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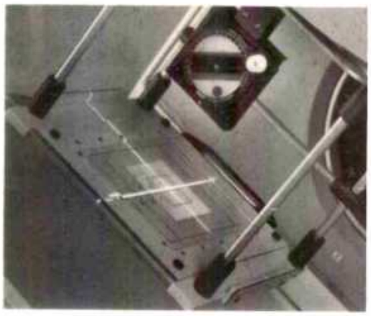

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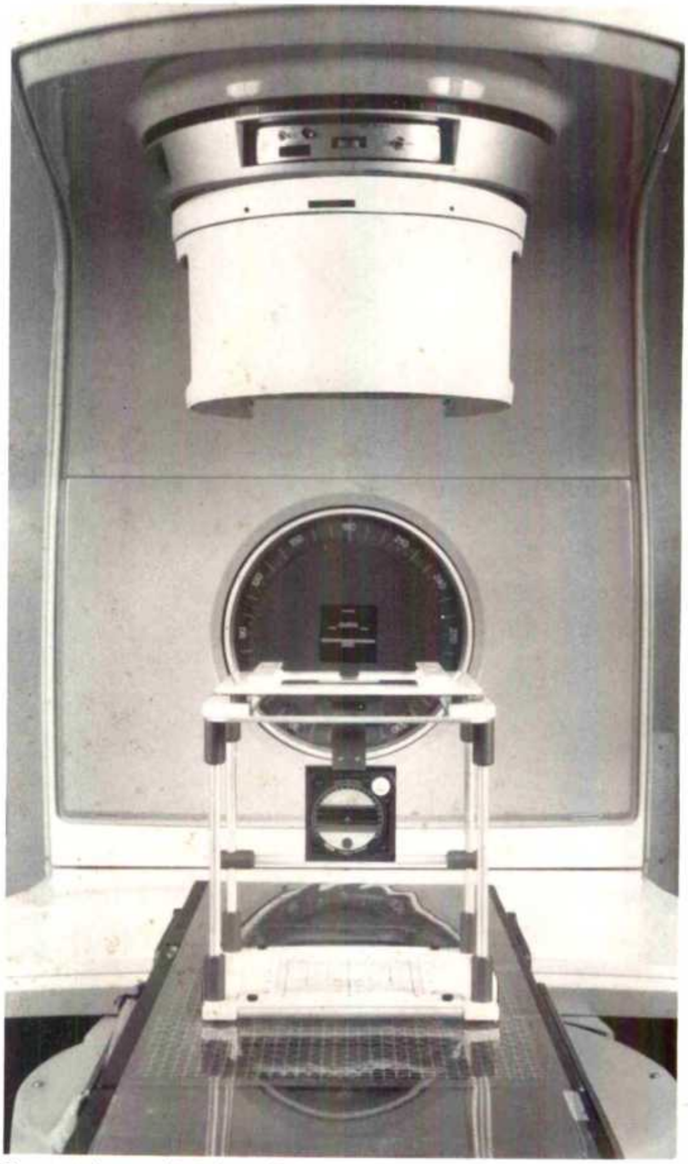

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Radiographic videodensitometry for quantitative monitoring of experimental bone healing

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(Received November 1988 and in revised form May 1989)

Abstract. A method for non-invasive assessment of experimental bone healing in animals is described. Optimized radiographs were analysed by digital processing using a computer-based image analysis system. Values of the total mass were expressed as the equivalent mass of a simultaneously exposed aluminium roentgen-density reference. In order to assess the potential of the method, measurements were initially performed on phantoms and bone specimens. The systematic error was negligible. An excellent correlation ($r = 0.999$) was found between the densitometric weight (μ) and the corresponding dry weight (m) of the analysed bone samples and a calibration factor $\mu/m = 1.38$ was established. The total random error was low, the coefficient of variation (CV) amounting to $<5\%$ or, if duplicate analyses were performed, $<3\%$. The accuracy was not impaired when radiography was carried out with addition of water to mimic overlying soft tissue in the model. The method was applied to the assessment of callus mass longitudinally *in vivo* in the healing of a bone defect in the rabbit radius, yielding reproducible values ($CV < 5\%$) and a quantitative analysis of the healing sequence.

Adequate evaluation of experimental bone healing should include different analyses owing to the dynamic and complex nature of the callus response. Among these analyses, there must be an objective evaluation, *i.e.* a quantitative assessment. In principle, quantitative analyses may be either invasive or non-invasive.

Bone regeneration, for example following application of bone stimulating agents, can be studied in the rabbit by following the healing of a defect created in the radius (Wittbjer, 1983). Quantitative, invasive methods such as bone histomorphometry and mechanical testing (Bruce et al, 1987) as well as ash weight determinations and scintimetry of specimens (Aspenberg et al, 1986) have been used widely. However, although most of these methods may be reliable and valid, they are limited to a single evaluation. In addition, supplementary analyses are strongly restricted because of the specimen handling procedure, altering the internal organization or even destroying the specimen. Employing a non-invasive method would make possible further analyses, as well as longitudinal evaluations in time.

Wittbjer et al (1982) adopted scintimetric digital imaging in the radius defect model, but this method only reflects the metabolic activity, *i.e.* the intensity of the calcification process. Radiography has the advantage of being simple and easy to perform, demonstrating the mineral accretion process with good morphological resolution. However, this method is subjective and not very reliable in the assessment of bone healing (Nicholls et al, 1979). By evaluating the radiographs with planimetry, values of callus area are obtained (Wittbjer et al, 1983). Paley et al (1986) extended the radiomorphometric analysis by determining the callus volume from antero-posterior and lateral radiographs of the rabbit radius, using an image analyser system. Although these morphometric methods are non-invasive and quantitative, they yield no information as to the callus mass and its chemical constituents. In fact, the mass of the callus and the chemical composition [illegible], according to Aro et al (1985), better characterize the callus quantity.

Hence, a non-invasive, quantitative method providing information on bone mass with morphological resolution would be beneficial. Recently, we presented a new method for the determination of the total mass of microradiographed bone samples, using a computerized image analysis system (Kälebo & Strid, 1988; Strid & Kälebo, 1988). The method was applied to the assessment of callus bone tissue regenerated in titanium implants (Kälebo & Jacobsson, 1988).

The aim of the present study is to show that radiographic videodensitometry can be extended into a non-invasive, quantitative method for assessment of experimental bone healing in animal models.

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Materials and methods

Radiographic videodensitometry is a two-step process for the determination of the total mass of matter exposed to soft X radiation consisting of (i) radiography and (ii) computer-assisted videodensitometry. The mass of the object of interest is expressed in the equivalent mass of a simultaneously exposed roentgen-density reference material of known composition. The reference material is properly chosen to possess attenuation characteristics similar to those of the object. No assumption is needed as to a specific attenuation formula, *e.g.* the Lambert–Beer exponential law.

Radiography

Conventional X-ray equipment (Orbix, Siemens-Elema) with a tungsten anode generated a filtered (3 mm aluminium) constant-tension polyenergetic spectrum. A 0.6 mm × 0.6 mm (nominal) focus was used with a focus–film distance (FFD) of 100 cm. The object was put on a fine-grain, single-emulsion film (Mamoray MR 3, Agfa-Gevaert) enclosed in an envelope. No intensifying screens were applied. This ensured high spatial resolution and negligible magnification. The film was machine-developed in a 90 s process.

In order to select the appropriate exposure for optical densitometry of the rabbit radius, of ~4 mm thickness, a matching reference was designed in the form of a step-wedge made from 10 sheets of pure aluminium. The thickness of each step measured 0.55 mm (range ± 0.002 mm) and each step was 5 mm × 2.5 mm, the whole reference thus measuring 5 mm × 25 mm with the thickness 0.55–5.5 mm. Exposures were varied between 35 and 45 kV and 100 and 800 mAs. The light transmission of the film was determined as a function of the reference thickness by means of an optical densitometer (model 301, X-Rite Company) with a 2 mm circular aperture. The exposure resulting in optimal conditions for densitometry, *i.e.* a linear relation between light transmission and reference thickness and an optical (photographic) density varying between 0.5 and 1.3 (Henke et al, 1957) was obtained at 40 kV and 600 mAs (Fig. 1). This corresponds to a relatively narrow X-ray spectrum (centre at 30 keV, half-maximum width ± 7 keV), suitable for bone densitometry.

The background density of the exposed film was checked densitometrically to ensure homogeneity. Only radiographs with a variation in background optical density not exceeding ± 0.02 density units in the region of interest (30 mm × 30 mm) were accepted for videodensitometry.

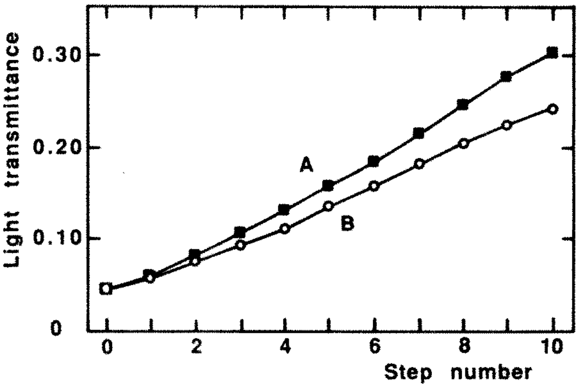

Figure 1. Relation between light transmission of the radiograph and path length through the aluminium reference step-wedge for 40 kV X radiation, with the wedge surrounded by air (A) or submerged in 7 mm of water (B).

Videodensitometry

A computer-based, interactive, image-analysis system (IBAS, Kontron Bildanalyse GmbH), previously described by Strid and Kälebo (1988), was used for analysis of the images. The system was provided with a television camera (Compact camera, type TYK 9 B, Robert Bosch GmbH, with a Newvicon tube, type XQ 1440) adapted for analytical procedures, connected to a macro zoom lens. Transilluminated images were entered and the video signal was analog-to-digital converted into a 256-level grey scale using a matrix of 512 × 512 picture elements (pixels). Each pixel represented a square of 20 μm sides.

A computer program was written to include all the necessary measurement procedures. A grey-scale calibration table was calculated by interpolation from the measurement of the step-wedge image. Length scales were calibrated along and perpendicular to the video scan lines by means of a graduated ruler. Hence, each radiograph was calibrated for radiographic density and area. Furthermore, the evenness of the background illumination was checked before scanning by the operator in interaction with the program. Thereafter, the image was entered. The measuring area was selected by the operator using a cursor in the monitor display. For each pixel in the selected area, the object transmission was converted into the equivalent path length through the aluminium reference. The total material content was then calculated as "aluminium equivalent mass", by integration over the measuring area. Beside the numerical value, a diagram of matter distribution along the object was presented (Fig. 2). A detailed description of the videodensitometric procedure has been presented by Strid and Kälebo (1988).

Assessment of the method

In order to assess and validate the present method, mass determinations were performed on bone-simulating phantoms and bone specimens.

Twenty aluminium specimens of varying shape and size, albeit in magnitude similar to the radial defect, were prepared from the same sheet as was used for the reference. Their mass, ranging from 3.5 to 140 mg, was determined accurately on an analytical balance (M-3, Mettler).

Ten bone specimens of about the same size as the

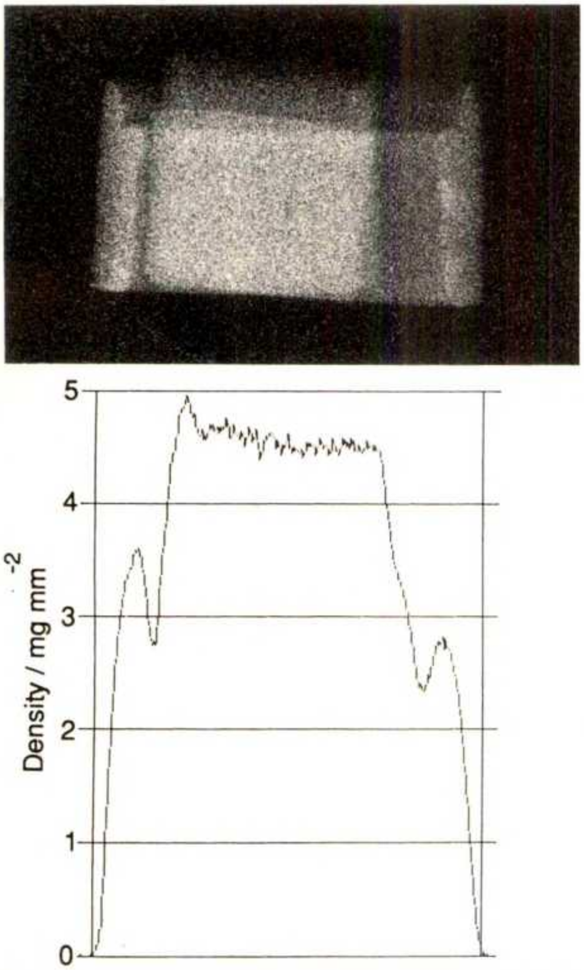

Figure 2. Radiograph of aluminium specimen no. 17 (*c.f.* Table I) and graph of measured average matter distribution. The optical density was measured along the video scan lines (horizontal in the figure) in the image area and converted into the corresponding matter–density profiles. The graph represents the average of those profiles.

aluminium phantoms were taken from the distal third of the radial diaphysis of an adult New Zealand rabbit. Overlying soft tissues were removed and the specimens fixed in a neutral formalin solution. After radiography of the wet specimens, the samples were dried to constant weight (100°C, 6 h) and their dry weight determined.

Radiography was performed by placing five samples on each side of the step-wedge reference. The reference was then carefully centred under the beam, perpendicular to the axis of the tube. Thus, 10 images were produced on each radiograph. Before densitometry, a few unevenly exposed or processed radiographs (see above) were rejected.

The densitometrically determined mass (μ) of the phantoms and bone specimens was compared with the weight determined by the balance (m), the latter determination being considered the reference analysis, the error in the balance being negligible. The systematic error of the method was assessed from the arithmetic mean of the ratio μ/m of the aluminium phantoms and bone specimens, respectively, and the random error was calculated from the standard deviation of this ratio.

In order to clarify the contribution of the soft-tissue component to the total radiographic attenuation in the radial defect model, the experiment with the aluminium phantoms was repeated with the reference and the phantoms submerged in a thin plastic tray containing a 7 mm water layer to simulate soft-tissue attenuation.

Application of the method

Longitudinal assessment of the callus content in a healing bone defect was performed in an adult New Zealand rabbit using a 6 mm long defect produced in the distal third of the radial diaphysis.

Radiography was performed as described above, with the forelimb positioned together with the step-wedge. In order to reduce the soft-tissue contribution to the total attenuation, compression of the tissue over the defect was carried out, reducing the limb thickness at the region of interest to ~7 mm. In addition, the reference was submerged in a 7 mm water bath, to mimic the overlying soft tissue. The callus mass was calculated as the mean value from duplicate radiographs of the same object. The location of the margins of the defect at later times was established by superimposing the reference radiograph, taken immediately following surgery, on the later radiographs.

The bone healing was followed weekly from the time of surgery to the 6th week. To assess the reproducibility of the mass measurement, duplicate analyses were carried out.

Results

Specimen mass evaluation

For each of the aluminium phantoms, the densitometrically determined weight, expressed as "aluminium equivalent mass" (μ), was compared with the conventional true weight (m) established by the balance. Two independent series of measurements of the 20 samples (Table I) showed the measuring method to yield a negligible systematic error, as demonstrated by the average values for the quotient μ/m of 1.000 and 0.996, respectively, for the two series. The random error was described by the coefficient of variation (CV) of μ/m, amounting to 3.2% and 4.3%, respectively; for an average of the two independent analyses the CV was calculated as 2.6%. To establish the stability of the method, the measurements were repeated at monthly intervals, resulting in CVs of the same magnitude.

The mass determinations of the bone specimens resulted in a mean value for μ/m of 1.378, the CV amounting to 2.7% (Table II). Although the shape and size varied between the samples, a linear regression analysis resulted in an almost perfect Pearson correlation coefficient, $r=0.999$ (Fig. 3).

Table I. Results of radiographic videodensitometry of 20 aluminium samples, using two independent evaluations

Sample number (i)	Conventional true weight m_i (mg)	Radiograph 1		Radiograph 2	
		Densitometric weight μ_i' (mg)	Ratio μ_i'/m_i	Densitometric weight μ_i'' (mg)	Ratio μ_i''/m_i
1	3.521	3.509	0.997	3.259	0.926
2	3.834	3.797	0.990	4.091	1.067
3	4.755	4.485	0.943	4.618	0.971
4	7.065	6.736	0.953	7.126	1.009
5	9.175	9.410	1.026	9.573	1.043
6	10.947	11.076	1.012	10.405	0.950
7	11.522	11.953	1.037	11.240	0.976
8	12.394	12.674	1.023	11.912	0.961
9	12.756	12.934	1.014	12.854	1.008
10	13.441	13.043	0.970	14.063	1.046
11	26.732	25.439	0.952	27.132	1.015
12	31.985	31.839	0.995	32.087	1.003
13	34.724	34.402	0.991	32.711	0.942
14	47.629	49.803	1.046	44.418	0.933
15	48.078	46.115	0.959	47.631	0.991
16	52.506	54.891	1.045	56.759	1.081
17	70.822	70.828	1.000	72.565	1.025
18	92.469	94.593	1.023	92.118	0.996
19	112.200	112.140	0.999	112.739	1.005
20	140.281	144.090	1.027	135.873	0.969
Mean			1.000		0.996
Standard deviation			0.032		0.043

The outcome of radiography when the reference and the bone-simulating aluminium phantoms were submerged in a 7 mm water bath was nearly identical to that of the initial experiment. Radiography with addition of water resulted in a decline of the contrast gradient compared with radiography in air, but the linearity was preserved (Fig. 1). The total random error in the determination of the 20 phantoms was described by a CV of 4.1%. The mean value was 0.99 and the systematic error, hence, negligible in comparison with the random error. The correlation coefficient between μ and m was excellent ($r = 0.998$; Fig. 4).

Quantification of bone healing

The healing pattern in the bone defect model could be monitored non-invasively without any significant

Table II. Comparison between densitometric weights (μ) and dry weights (m) of bone specimens from the rabbit radius

Specimen number (i)	μ_i (mg)	m_i (mg)	Ratio μ/m
1	5.346	3.946	1.355
2	11.415	8.260	1.382
3	28.456	20.255	1.405
4	31.339	21.776	1.439
5	29.830	22.160	1.346
6	33.055	23.571	1.402
7	31.534	23.919	1.318
8	75.972	55.265	1.375
9	86.244	61.021	1.413
10	110.642	81.947	1.350
Mean			1.378
Standard deviation			0.037
Coefficient of variation			0.027

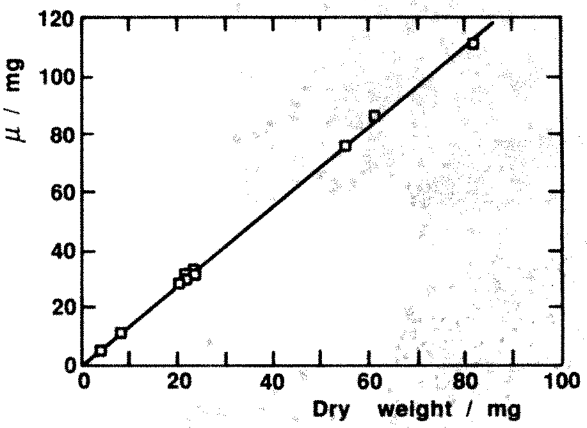

Figure 3. Regression analysis of "aluminium equivalent mass" (μ) against dry weight (m_{dry}) of rabbit bone specimens. The regression line is described by $\mu = 1.368 m_{dry} + 0.335$ (mg), yielding the correlation coefficient $r = 0.9993$.

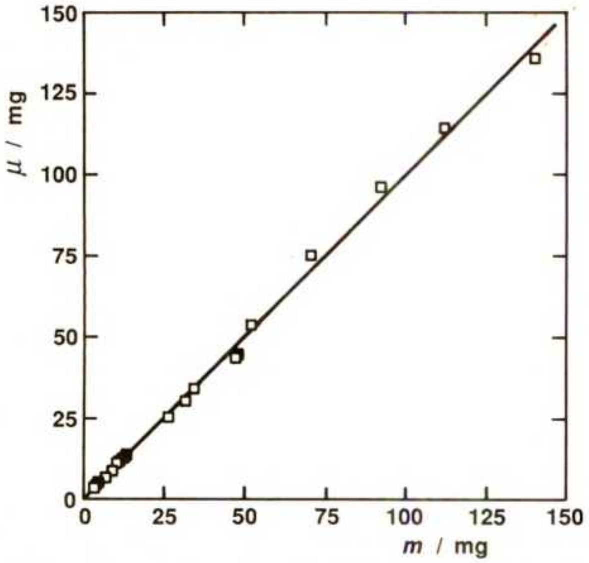

Figure 4. Regression analysis of densitometrically determined mass (μ) against weight (m) of aluminium samples immersed in 7 mm of water. The regression line is given as $\mu = 1.003\,m - 0.299$ (mg) with the correlation coefficient $r = 0.998$.

Table III. Longitudinal callus mass in a rabbit bone healing model. The mass was determined twice, each determination comprising two independent radiographic–videodensitometric measurements, and the reproducibility calculated

Time (weeks)	Analysis I (mg)	Analysis II (mg)	Ratio (I/II)
0	7.921	8.750	0.905
1	14.474	14.088	1.027
2	60.868	59.076	1.030
3	81.712	84.770	0.964
4	92.703	91.352	1.015
6	94.942	93.374	1.017
Mean			0.993
Standard deviation			0.049

inconvenience. The reproducibility in the callus mass determinations was good, the CV amounting to <5% (Table III).

The initial measurement from the first post-operative radiograph resulted in a bone mass value of ~8 mg, indicating a small discrepancy in the attenuation between soft tissue and water. After 1 week, the callus mass was slightly higher, ~14 mg (Table III). Between the 2nd and 3rd week, there was an intense mineral accretion, as indicated by the marked increase in callus mass, up to ~80 mg. At 4 weeks, the bone healing response reached a plateau with respect to mass, and it was only slightly higher after 6 weeks, the mass amounting to ~94 mg. In this later period, the remodelling phase dominated, as more ordered bone was observed at this time compared with the amorphous callus seen during the first weeks (Fig. 5).

Discussion

Radiographic photodensitometry is an old-established method for evaluation of the bone mineral content of extremities (Engström & Welin, 1949; Mack et al, 1949). While other radiological, non-invasive methods have been developed for different anatomical sites (reviewed by Andresen & Nielsen, 1986; Hangartner, 1986), radiographic densitometry of the

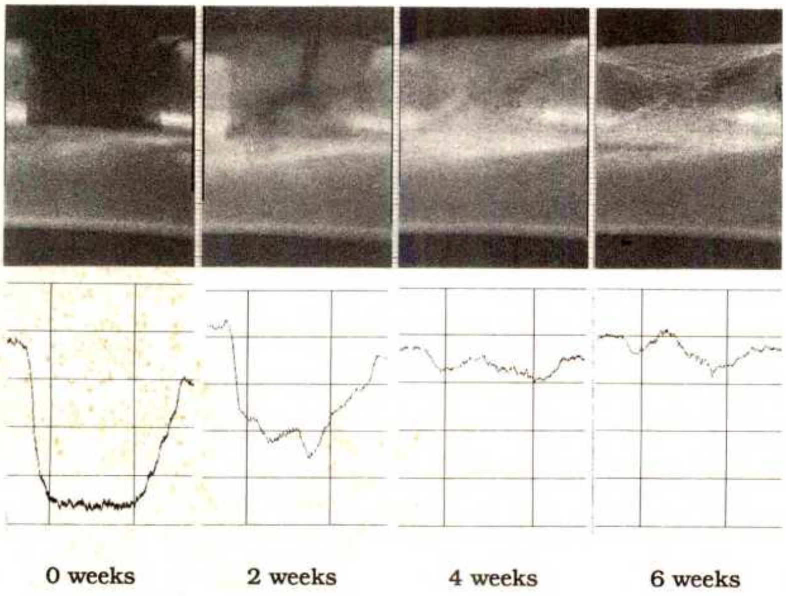
0 weeks 2 weeks 4 weeks 6 weeks

Figure 5. Radiographs of healing bone defect in rabbit radius and the associated representations of measured average distribution of mineralized bone (*c.f.* Table III). The measuring area (*c.f.* Fig. 2) was limited to contain only the radial defect.

fingers is still used for metabolic bone studies (Colbert & Bachtell, 1981).

In the study of experimental bone healing, the method has been almost exclusively limited to point measurements on specific parts of the callus (*e.g.* Paley et al, 1986; Sartoris et al, 1987), using optical microdensitometers. Vose et al (1961) adopted line scanning over a healing cortical defect in the rat tibia. These scanning procedures are, however, restricted to a selected area in the healing region and therefore reflect incompletely the overall healing response in the region considered. In addition, since the callus growth is not geometrically even (McKibbin, 1978), it would be better to evaluate the total callus content in the entire defect. Thus an area analysis should be performed. Single photon absorptiometry (SPA) is an alternative technique, but not frequently used in studies of bone healing (Hellewell & Beljan, 1979; Köhler, 1986). Although accurate values may be obtained with SPA, the morphological information produced will be limited.

The present method applied to total mass determinations from radiographs has shown accurate analyses to be feasible with total random errors $<5\%$ and negligible systematic errors. The choice of proper exposure conditions, high-resolution film and image quality control in conjunction with an accurate image analysis system contributed to the good result. The errors in this method stem mainly from the radiographic procedure. Consequently, the accuracy is increased if duplicate radiographs are analysed instead of single ones, the radiographic error thereby being reduced to yield a total $\text{CV} < 3\%$, for *in vitro* evaluations.

Aluminium proved to be a good densitometrical reference in the present study. A linear relationship was obtained between densitometric mass (μ) and dry weight (m), both for phantoms and for bone specimens, which corroborates the findings by Schraer et al (1959), who performed a similar test of rat femur samples. The mean value of the ratio μ/m for the analysed bone specimens, 1.38, which is used as a calibration factor, is in good agreement with the corresponding value for microradiographic–videodensitometric analysis of rabbit cortical bone samples, *viz.* ~ 1.39 (recalculated from Kälebo & Strid, 1988). If the wet bone weight had been used as a reference, this value would have come closer to 1. However, weighing of wet bone will yield unreliable results. A further source of discrepancy is the slight difference in effective atomic number (Z_{eff}) between rabbit bone ($Z_{\text{eff}} \approx 14$) and the aluminium reference ($Z = 13$), which influences the attenuation coefficient by the cube (Kälebo & Strid, 1988). Indeed, rabbit cortical bone has a relatively high mineral content compared with other species (Biltz & Pellegrino, 1969), which results in a somewhat higher Z_{eff} value and, thus, radiographic attenuation.

The soft tissue does contribute to the total attenuation process. This fact was observed by Jackson (1951), who reduced this influence on radiographic bone density evaluations by submerging the reference and the bone in water, relying on the fact that the Z_{eff} values of soft tissue and water are similar. The use of a water-bath to allow for soft-tissue attenuation was confirmed by Baker et al (1959), who found that as long as the overlying soft-tissue layer is thin and the bone thickness small (resulting in a relative low water and fat content in the bone), as for example in fingers, there is a good correlation between the densitometrically determined mass of an intact finger and the dry bone weight. Evaluations of thicker bones, *e.g.* femur and humerus, with a larger soft-tissue layer and a higher internal water and fat content, by the radiographic–densitometric method were not reliable (Baker et al, 1959). In the case of the rabbit radius the slight thickness (~ 4 mm) and the thin soft-tissue layer following compression results in a thin limb, of ~ 7 mm thickness, which favours non-invasive radiographic videodensitometry.

The possibility of quantitative monitoring of bone healing is evident as indicated by the result in the present study. Reproducible values of total callus mass are obtained. This method, producing absolute mass values in contrast with the relative ones as obtained by several of the other quantitative methods, allows intra- as well as interindividual comparisons. The radiographs produced immediately post-operatively appear to be influenced by the occurrence of oedema as reflected by a non-zero value of "aluminium equivalent mass" in the resection area. However, this will not affect the conclusions to be drawn from a longitudinal study of bone healing.

Other applications of the method are possible, as long as the bone is of dimensions in the same order of magnitude as the rabbit radius with an equivalent soft-tissue component. In man, quantitative analyses *in vivo* of finger phalanges are likely to be possible. The method is also applicable to small bone biopsies. In fact, the clinical use of radiographic image analysis, with emphasis on bone morphometry, has been presented by Meema (1986) and Browne et al (1987). Recently, Brägger et al (1988) introduced a computer-assisted densitometric image analysis method for quantification of alveolar bone density changes in periodontal radiography.

The authors believe that this new method will facilitate the examination of mineralized tissue, irrespective of its type, such as callus, cancellous, cortical or composite bone.

Acknowledgments

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Alimentary tract lesions in Cowden's disease

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Abstract. Cowden's disease was first recognized by its striking dermatological manifestations and subsequently by the increased incidence of neoplastic involvement of the thyroid and breast. Two cases of Cowden's disease with gastrointestinal polyps are presented to illustrate the alimentary tract involvement in this syndrome, gastrointestinal tract involvement with polyposis being seen in at least 50% of cases. As opposed to the more serious potential of neoplasia in the thyroid and breast, involvement of the alimentary tract has negligible clinical impact to the patient.

Cowden's disease is a clinical complex manifest by hamartomas developing in tissues originating from all three embryonic germ layers. Initially the syndrome was named after the propositus, Rachel Cowden, and reported by Lloyd and Dennis (1963). In 1972, Weary et al suggested the name "multiple hamartoma syndrome". The syndrome is being diagnosed more frequently and is probably more common than suggested by the 100 case reports in the medical literature. Because the most common and most obvious characteristic of the condition relates to mucocutaneous lesions, it is not surprising that most of the reported cases appear in the dermatology literature. As this syndrome has been more fully evaluated, however, frequent involvement of the gastrointestinal tract is now recognized. The purpose of this report is to: (1) describe two new cases of Cowden's disease, each with alimentary tract involvement, (2) review the medical literature regarding the gastrointestinal lesions and (3) reinforce important associated findings in the disease.

Case reports

Case 1

A 54-year-old woman was seen initially in May 1979 at the Milwaukee County Medical Complex complaining of "garbled" speech of 4-months duration. She had no difficulty in swallowing or aspiration. Her past medical history included a right hemithyroidectomy in 1954 for thyroid enlargement associated with Hashimoto's disease and a right mastectomy for breast carcinoma in 1957. Four of her sisters had surgical disease of the thyroid while one daughter had a medullary thyroid carcinoma. On physical examination, multiple, wart-like maculae were noted on her face as well as on the skin of her hands and feet. Otherwise, her physical findings were normal. Evaluation of the patient's dysarthria showed normal swallowing and her vocal cords appeared normal. A diagnosis was made of "idiopathic spastic dysphonia". A dermatology consultation for her mucocutaneous maculae led to the diagnosis of Cowden's disease. A barium study of the upper gastrointestinal tract and small bowel revealed numerous, small, 2–5 mm polypoid lesions in the gastric antrum (Fig. 1). The oesophagus, duodenum and small bowel appeared normal. Gastroduodenal endoscopy confirmed the presence of numerous 2–5 mm antral polyps, which, on biopsy, were judged to be hyperplastic. Several small polyps were seen in the proximal stomach and proximal duodenum while the oesophagus was normal. Subsequent air-contrast examination of the colon and colonoscopy showed no evidence of abnormality. In 1980, the patient underwent a left nephrectomy for hypernephroma. Her residual thyroid, removed in 1983 for progressive enlargement, showed histological findings of follicular hyperplasia and Hashimoto's thyroiditis. The patient has been without evidence of subcutaneous tumours or any alimentary tract symptoms.

Case 2

A 41-year-old white man was diagnosed as having Cowden's disease in 1985 when physical examination showed multiple facial trichilemmomas, gingival papillomatosis and a high-arched palate. The patient had a past medical history of bilateral parotid hamartomas, resected at age 26 years. He had also had previous surgery for "retroperitoneal fibrosis" when embryonic renal elements were present. At age 27 years the patient underwent endoscopy and a benign, 2 cm colonic polyp was removed. He also had two partial thyroid resections for benign adenomatous changes in the gland. A double-contrast upper gastrointestinal study showed innumerable, small, sessile polyps in the oesophagus (Fig. 2) and further polyps scattered throughout the stomach. No abnormality was demonstrated in the duodenum. A recent barium enema was normal. Endoscopy showed a diffuse carpet of oesophageal polyps ranging from 2 to 8 mm in size, numerous gastric polyps measuring 2–3 cm and scattered polyps, 3–5 mm, in the duodenum. Histological examination of those from the oesophagus and stomach demonstrated inflammatory polyps.

Discussion

Since the initial description of the dermatological abnormalities by Lloyd and Dennis in 1963, there has been increased recognition of the complex manifestations of Cowden's syndrome. It has an autosomal dominant inheritance with about one-third of the patients having a positive family history (Salem & Steck, 1983). A recent review of the English medical literature reported a slight predominance of females, with a sex ratio of 1.5:1 (Allen et al, 1980). The

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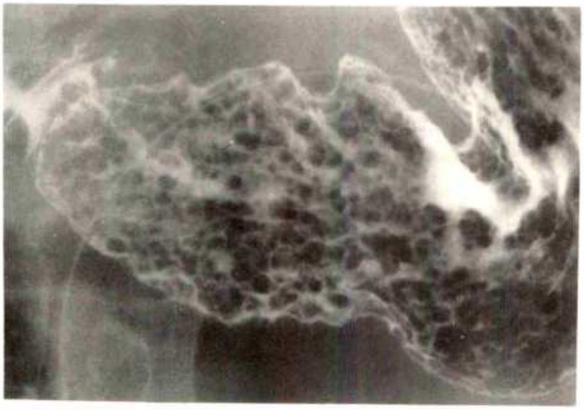

Figure 1. *Case 1.* Magnified view from a double-contrast examination showing numerous, small, sessile polyps, 2–5 mm in diameter, covering the entire gastric antrum.

diagnosis of Cowden's disease is usually made when the patients are 13–65 years of age, with a mean age of 22 years (Salem & Steck, 1983).

There are various theories regarding the pathogenesis of the disease. Some researchers implicate an epidermal growth factor. This *in vivo* substance stimulates the growth of skin (Cohen & Taylor, 1974), alimentary tract mucosa (Scheveing et al, 1980), breast (Cohen & Taylor, 1974) and thyroid (Westermark et al, 1983), all of which are involved in Cowden's disease. Although elevated blood levels of epidermal growth factor have not been found in patients with Cowden's syndrome, there could be increased local production or increased receptor cell sensitivity (Carlson et al, 1986). Other, as yet unknown, growth factors may also be present.

The *sine qua non* for the complex of Cowden's disease is the characteristic mucocutaneous trichilemmomas and other varicoid papular lesions on the central facies, oral mucosa, hands and/or dorsal aspect of the forearms. These skin lesions are usually manifest by the second decade (Burnett et al, 1975; Starink et al, 1986; Chen et al, 1987). A cobblestone appearance of the tongue is another frequent finding. Adenoid facies, hypoplasia of the mandible, craniomegaly and a high-arched palate are also common features (Ortonne et al, 1980; Salem & Steck, 1983).

Several life-threatening conditions are associated with Cowden's syndrome. Abnormalities of the thyroid, which occur in about two-thirds of cases, include adenomas, goitre and carcinoma (Allen et al, 1980; Salem & Steck, 1983; Lashner et al, 1986; Chen et al, 1987). Cowden's disease has also been shown to be a cutaneous marker for breast carcinoma, which may occur in up to half of the female patients (Brownstein et al, 1978; Allen et al, 1980). In one series, 39% of patients had at least one malignancy. Breast carcinoma occurred in 36% of cases and thyroid carcinoma in 12% (Salem & Steck, 1983). Numerous isolated cases of benign visceral tumours and hamartomas have been described (Nuss et al, 1978; Gold et al, 1980; Salem & Steck, 1983). One of our patients (Case 2) had bilateral parotid hamartomas, a finding that has not been reported previously.

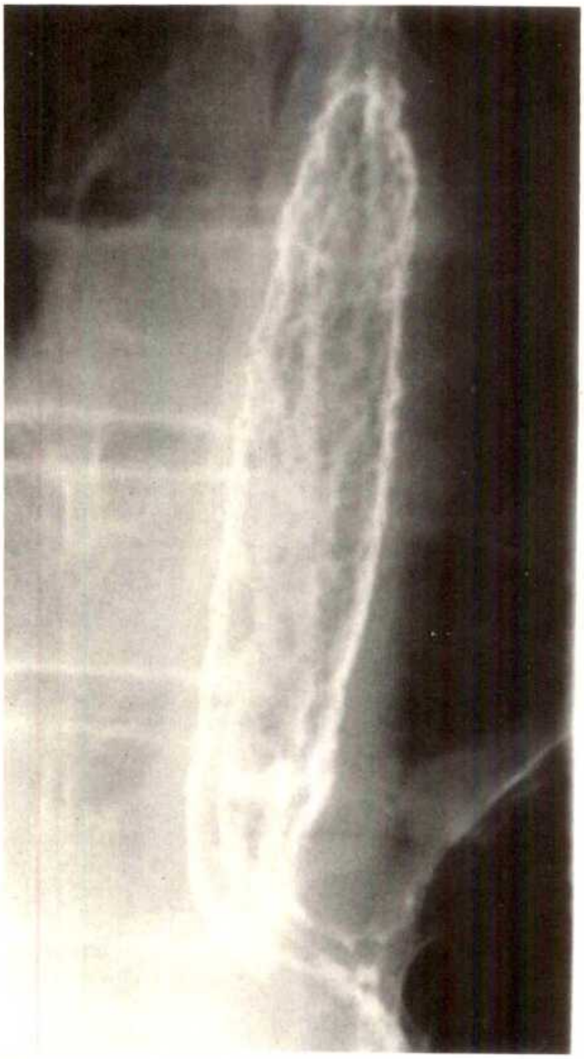

Figure 2. *Case 2.* Coned view from a double-contrast examination demonstrating a carpet of sessile polyps, 2–8 mm in diameter, in the distal oesophagus.

Both our cases illustrate the possibility of diffuse regional involvement of the gastrointestinal tract. A recent review indicates that only 53% of the reported cases with Cowden's disease have had some form of gastrointestinal tract investigation, but in patients undergoing evaluation of the entire alimentary tract, 71% demonstrate gastrointestinal tract involvement (Allen et al, 1980).

The polyps may occur throughout the gastrointestinal tract or be localized to one or several segments. The true distribution, however, is difficult to assess because of the lack of a complete gastrointestinal examination in most patients. The alimentary tract polyps vary in size from 1 to 3 cm. In general, the polyps tend to be tiny, necessitating meticulous radiological technique. Many exhibit numerous polyps, similar to those in the stomach in Case 1 and the oesophagus in Case 2. The pathology of the polyps varies and is not specific in any particular area. The histological findings include hamartomatous, hyperplastic, inflammatory and adenomatous lesions (Weary et al, 1972; Weinstock & Kawanishi, 1978; Allen et al, 1980; Thyresson & Doyle, 1981). Also reported, but less common, are ganglioneuromatous, glycogenic acanthosis (Lashner, 1986), fibrous (Elston et al, 1986), hyperplastic, epithelioid leimyomatous (Gentry et al, 1975; Carlson et al, 1984) and juvenile polyps.

Although a high incidence of polypoid alimentary tract lesions exists in Cowden's syndrome, they seem to cause negligible morbidity and mortality. A few isolated reports exist of colonic carcinoma, but the association with Cowden's syndrome is doubtful (Allen et al, 1980; Snover, 1987).

The differential diagnosis of multiple gastrointestinal polyps includes familial polyposis coli, Gardner's syndrome, Peutz-Jegher's syndrome, Canada-Cronkhite syndrome, lymphoma, lymphoid hyperplasia and juvenile polyposis. When polyps are limited to the oesophagus, then inflammatory processes such as candidiasis and Herpes simplex might be a consideration. In all cases, however, the correct diagnosis of Cowden's syndrome is confirmed by a careful search for the typical mucocutaneous lesions that are invariably present.

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Fatigue fractures of the femoral diaphysis in the skeletally immature simulating malignancy

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Abstract. The clinical and radiological features of three fatigue fractures developing along the medial aspect of the distal femoral diaphysis are described. All three patients were skeletally immature and were referred with the radiographic diagnosis of a probable sarcoma of bone. The plain radiographic findings consisted of an uninterrupted single lamella of periosteal new bone arising medially from the distal femoral diaphysis. Bone scans showed no evidence of hyperaemia on the vascular phase and revealed a fusiform focus of increased uptake in the postero-medial cortex of the lower femoral diaphysis on the 3-h images. Computed tomography showed increased attenuation of the medulla due to fibrosis and an absence of a soft-tissue mass. Periosteal callus was present and a cortical fracture through the medial femoral cortex was identified in two cases. The features that distinguish a fatigue fracture of the femur from a sarcoma are discussed.

The fatigue form of stress fracture can cause diagnostic difficulties in that the healing fracture may often be mistaken for a malignant lesion (Levin et al, 1967; Provost & Morris, 1969; Solomon, 1974; Daffner et al, 1982; Arrivé et al, 1988). The tibia is the commonest site for fatigue fractures in the adolescent and young adult (Giladi et al, 1983; Matheson et al, 1987) and also the commonest site to be misinterpreted radiologically as a sarcoma of bone (Davies et al, 1988). An uncommon but unusual site where similar problems may occur is the shaft of the femur (Levin et al, 1967; Burks & Sutherland, 1984).

The purpose of this paper is to review the radiological investigations of three such cases recently referred to the Birmingham Bone Tumour Treatment Service and discuss the bone scan and computed tomographic (CT) features that help distinguish a stress fracture from a sarcoma of bone.

Patients and methods

In a 15-month period commencing October 1987, three patients referred to the Birmingham Bone Tumour Service with the diagnosis of a probable malignant sarcoma of the femoral diaphysis were found to have a fatigue fracture. The medical records, plain radiographs, bone scans and CT examinations of the three cases are reviewed. The records of the Birmingham Bone Tumour Treatment Service were also reviewed to determine the total number of femoral lesions referred to the unit in the same period.

Results

The clinical details and pre-referral diagnoses of the three cases are summarized in Table I. All three were skeletally immature and none gave a history of acute trauma to the limb or remembered a recent increase in physical activity prior to the onset of symptoms.

The consistent plain radiographic appearance was of a single uninterrupted lamella of periosteal new bone arising medially in the lower femoral diaphysis (Figs 1, 2). In one case the periosteal reaction extended posteriorly to be visible on the lateral radiograph

Table I. Clinical details and pre-referral diagnoses of three patients with fatigue fractures of the femoral diaphysis

Case	Age	Sex	Side of fracture	Duration of pain (weeks)	History of trauma	History of increased physical activity	Examination findings	Pre-referral diagnosis
1	5 years 9 months	F	Right	4	—	—	Minor swelling of thigh	?Ewing's
2	15 years	M	Right	12	—	—	Normal	?Ewing's
3	15 years	M	Left	6	—	—	Tender antero-medial thigh	?Ewing's ??Post-traumatic ??Infective

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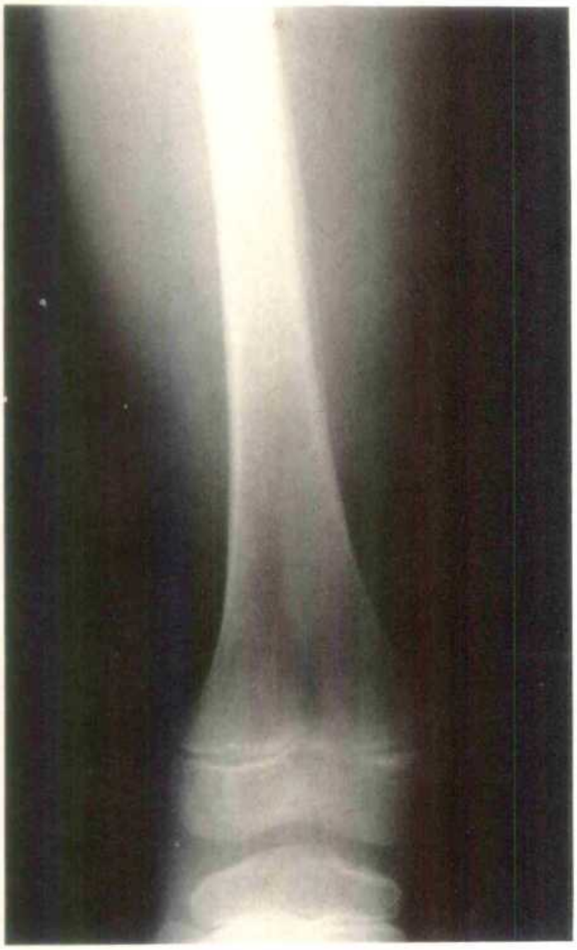

Figure 1. *Case 1.* Antero-posterior radiograph showing a single lamellar periosteal reaction arising from the medial aspect of the distal femoral diaphysis.

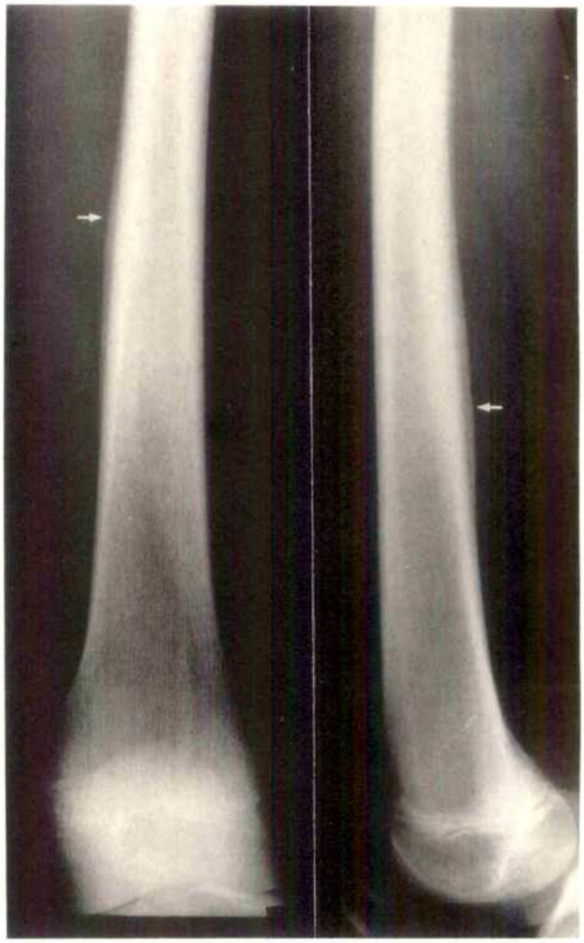

Figure 2. *Case 2.* Antero-posterior and lateral radiographs showing a single lamellar periosteal reaction arising from the medial and posterior aspects of the distal femoral diaphysis.

(Fig. 2). Follow-up radiographs obtained several weeks later demonstrated an uninterrupted bilamellar periosteal reaction in one case and filling in of the subperiosteal lucency in the remaining cases to form localized cortical hyperostosis.

Bone scans were performed in two cases. The vascular phase was normal in both examinations and the 3-h images revealed a localized, fusiform focus of increased activity, orientated longitudinally in the postero-medial cortex of the lower femoral diaphysis (Fig. 3) corresponding to the site of the plain radiographic changes.

On the soft-tissue window, CT showed no evidence of a soft-tissue mass and the attenuation of the femoral medulla was increased for an average of 10 cm around the fracture (Fig. 4a). On a bone window, periosteal, and to a lesser extent endosteal, new-bone formation was evident and in two cases the fracture was visible medially, deep to the vastus medialis muscle and just anterior to the lucency of the nutrient channel (Fig. 4b).

Within the 15 months of the study period, a total of 86 femoral lesions were referred to the Birmingham Bone Tumour Service. Eighteen cases arose in the femoral diaphysis, of which seven were histologically proven to be primary sarcomas of bone (five Ewing's tumours and two osteosarcomas). Fatigue fractures of the femoral diaphysis were the second commonest diagnosis after Ewing's tumour but were the commonest diagnosis if only skeletally immature patients were considered.

Discussion

Owing to the increase in both awareness of the subject and the application of bone scanning as an imaging technique, fatigue fractures have been detected in almost every bone that may be subjected to repetitive muscular stresses. The distribution of stress fractures differs considerably between the various studies. Historically the incidence of femoral fractures was quoted at less than 5% (Darby, 1967; Wilson & Katz, 1969), but with

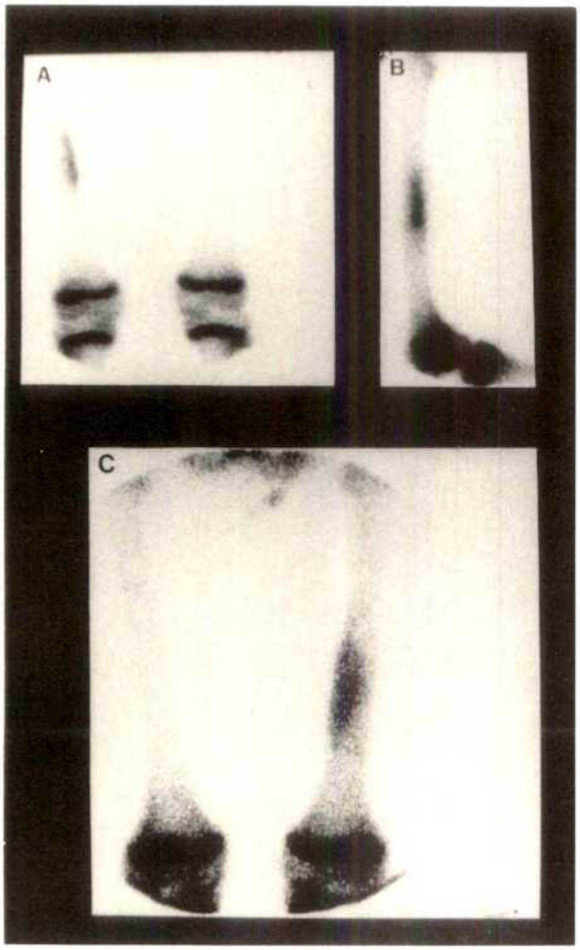

Figure 3. (a, b). *Case 3.* Three-hour frontal and right lateral bone scan images showing a fusiform focus of increased activity in the postero-medial cortex of the right distal femoral diaphysis. (c) *Case 2.* Three-hour frontal bone scan image showing a fusiform focus of increased activity orientated longitudinally in the medial cortex of the left distal femoral diaphysis.

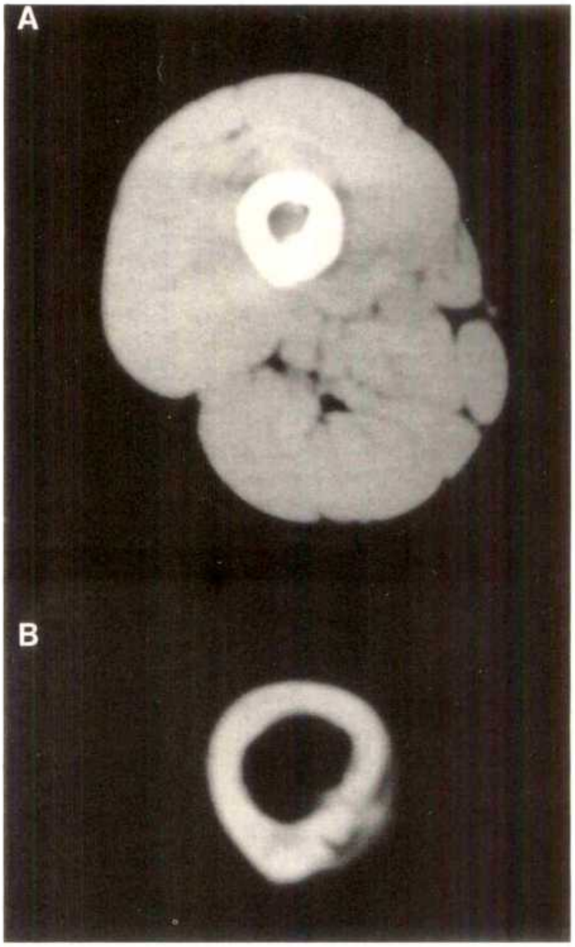

Figure 4. *Case 3.* (a) Axial CT scan on a soft-tissue window (WW 230, WL 30) showing increased attenuation of the femoral medulla and an absence of a soft-tissue mass or bony destruction. (b) Same level on an extended bone window (WW 2700, WL 1000) showing periosteal new-bone formation medially with the defect of the fracture line lying anterior to the lucency of the nutrient channel.

the introduction of bone scanning the incidence has risen to between 9 and 27% of all stress fractures (Prather et al, 1977; Meurman & Elfving, 1980; Giladi et al, 1983; Greaney et al, 1983). These studies, however, were on skeletally mature patients, the majority of whom were military recruits. Fatigue fractures of the femoral shaft in the child and adolescent, as exhibited in these three cases, are still relatively rare (Burks & Sutherland, 1984). In one study on stress fractures in children, there was not a single fatigue fracture of the femoral diaphysis (Devas, 1963).

Whilst fatigue fractures of the femoral diaphysis may be uncommon, so are primary sarcomas of bone, such that in this study a fatigue fracture was the commonest diagnosis of the femoral diaphyseal lesions presenting in skeletally immature patients. Similarly, proximal tibial fatigue fractures have been shown to be the second equal commonest diagnosis of all tibial lesions referred to a bone tumour centre (Davies et al, 1988).

It is to be expected that in the age group particularly susceptible to developing a sarcoma, a patient presenting with pain and periosteal new bone along the femoral shaft may be mistaken to have a malignancy (Levin et al, 1967; Solomon, 1974; Burks & Sutherland, 1984). It is undoubtedly the periosteal reaction on the plain radiographs that prompts the radiologist to suggest a sarcoma (Arrivé et al, 1988; Davies et al, 1988). However, the typical site along the medial cortex of the lower femoral diaphysis, the uninterrupted nature of the periosteal new bone (Figs 1, 2) and absence both of a soft-tissue mass and associated bone destruction should enable the radiologist, aware of this diagnostic entity, to make the diagnosis with confidence.

If there is any doubt, both bone scanning and CT can be helpful in confirming the diagnosis thereby excluding the need for biopsy, which itself is invasive, may precipitate complete fracture of the underlying bone and is not diagnostically infallible. The absence of significant hyperaemia on the vascular/dynamic phase of a bone scan will tend to suggest a stress fracture (Park et al, 1981; Collier et al, 1984; Rupani et al, 1985; Davies et al, 1988) rather than a sarcoma, which would exhibit marked hyperaemia. Characteristic of a stress fracture on the 3-h images is a fusiform focus of increased activity, orientated longitudinally and eccentrically situated in the bone, *i.e.* cortically located (Fig. 3) (Crass & L'Heureux, 1981; Collier et al, 1984; Rupani et al, 1985; Davies et al, 1988) whereas the activity seen with either a sarcoma or infection would be expected to involve the whole width of the shaft of the bone.

Computed tomography will confirm the absence of a soft-tissue mass although early in the development of the fatigue fracture, adjacent low-density, soft-tissue oedema, not present in the current cases, may be identified (Somer & Meurman, 1982; Davies et al, 1988). The attenuation of the medulla around the fracture site is increased (Fig. 4a). This is a non-specific finding due to hyperaemia and fibrosis associated with active callus formation (Somer & Meurman, 1982; Yousem et al, 1986) and should not be interpreted as indicative of intraosseous tumour tissue (Arrivé et al, 1988; Davies et al, 1988). On a bone window, CT will reveal the reparative process, demonstrating both periosteal and endosteal new-bone formation. Some published reports have had limited success showing the fracture line on CT (Somer & Meurman, 1982; Burks & Sutherland, 1984) but with a state-of-the-art scanner and careful attention both to the examination and image processing, the lucency of the fracture is evident in the majority of cases (Fig. 4b) (Murcia et al, 1982; Yousem et al, 1986; Davies et al, 1988).

Just as the fracture may be misinterpreted as a sarcoma, normal variants such as nutrient channels and lucent fissures in the posterior femoral cortex (Keats, 1988) should not be mistaken for the fracture line. Nor should the posterior cortical thickening of the linea aspera–pilaster complex (Pitt, 1982) be thought to be evidence of a healing fracture.

In conclusion, the radiological findings in three cases of a fatigue fracture of the distal femoral diaphysis in skeletally immature patients are presented. Although an uncommon site for a stress fracture, the appearances are sufficiently similar to be considered typical and the radiological investigations can prove diagnostic in the differential diagnosis of a malignant bone tumour.

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Small hepatocellular carcinoma: detection with sonography, computed tomography (CT), angiography and Lipiodol-CT

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Abstract. Seventy-three small hepatocellular carcinomas under 5 cm in diameter in 47 patients were examined by sonography, computed tomography (CT), hepatic angiography and CT after intra-arterial injection of iodized poppy-seed oil (Lipiodol-CT). The imaging techniques that first led to detection of small hepatocellular carcinomas were sonography in 53 cases (72.6%), CT in 10 (13.7%), angiography in eight (11%) and Lipiodol-CT in two (2.7%). Sensitivity for detecting small hepatocellular carcinomas was 73% with sonography, 82% with CT, 86% with angiography and 96% with Lipiodol-CT. As a screening method, sonographic and CT results in detecting small hepatocellular carcinomas were not significantly different ($p > 0.05$). Lipiodol-CT was superior to sonography ($p < 0.01$), CT ($p < 0.01$) and angiography ($p < 0.05$) in detecting small hepatocellular carcinomas. We believe that the combined use of Lipiodol-CT with screening methods such as sonography or CT is indispensable for the accurate detection of small hepatocellular carcinomas.

Hepatocellular carcinoma (HCC) is one of the most common malignant tumours in South-east Asia and sub-Saharan Africa (Sheu et al, 1985) and the prognosis is extremely poor because of the difficulty in early detection and its frequent association with cirrhosis. Because surgical resection is the most effective treatment of HCC, the detection of small HCCs becomes important for the determination of resectability. Fortunately, recent advances in liver imaging techniques such as scintigraphy, sonography, computed tomography (CT) and angiography make it possible to detect small HCCs, and asymptomatic HCC is more frequently recognized now than in the past (Inamoto et al, 1983; Shinagawa et al, 1984; Kudo et al, 1986; Takayasu et al, 1986). In addition, CT after intra-arterial injection of iodized poppy-seed oil (Lipiodol, Guerbet) was introduced for detection and treatment of HCC and has been acknowledged as the best method to detect small lesions (Ohishi et al, 1985; Yumoto et al, 1985).

However, review of previous reports (Inamoto et al, 1983; Shinagawa et al, 1984; Matsui et al, 1985; Sheu et al, 1985; Kudo et al, 1986; Takayasu et al, 1986) reveals that a variety of techniques and scanners were used for sonographic, CT and angiographic evaluation of small HCCs and that accuracy for each examination has varied widely, thus raising questions about the comparative efficacy of each examination. Furthermore, no comparative analysis of sonography, CT, angiography or CT after intra-arterial injection of Lipiodol (Lipiodol-CT) in a large population of patients with small HCCs has yet been reported in the English literature.

We compared the diagnostic accuracy and limitation of these four methods and studied their contributions to the evaluation of small HCC.

Materials and methods

During a 30-month period, 66 patients passed through Seoul National University Hospital with a diagnosis of small HCC, which was defined as one in which the largest dimension was less than 5 cm. Sixty of these patients had sonograms and 61 had CT scans. All 66 had hepatic angiography and Lipiodol-CT. A retrospective review was performed, and only those patients who had undergone all four examinations were included. These criteria allowed only 47 of the 66 patients to be included in the study. The series included 40 men and seven women, 39–72 years of age (mean age 56 years). The diagnosis of HCC was made by surgical resection of 33 tumours in 27 patients, including one tumour in 22 patients, two tumours in four patients and three in one patient. The remaining 20 patients were unable to undergo surgery for reasons including patient's refusal (six patients), accompanying severe cirrhosis (eight) and multiple tumours in both lobes (six); in these, the diagnosis was made by aspiration biopsy in five and elevated serum α-fetoprotein (AFP) levels or characteristic angiographic findings in 15 patients.

Clinical and laboratory data were reviewed in all patients. Most had chronic liver disease. Hepatitis-B surface antigen (HBsAg) was positive in 34 patients (75%) and hepatitis-B surface antibody (HBsAb) was positive in nine (19%). Liver cirrhosis was found in 40 patients (85%). Thirteen (28%) had a normal serum AFP level (<20 ng/ml) and 11 (23%) had an AFP level of 20–400 ng/ml. In 23 (49%), serum AFP levels were above 400 ng/ml.

Sonographic examination was performed on real-time scanners using Aloka SSD 280, Toshiba SAL 35A and

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Table I. The imaging technique that first led to detection of small HCC

Technique	Number of tumours (%)	No. of patients (%)
Sonography for:		
abnormal liver function test or liver cirrhosis	47 (64.4)	37 (64.9)
unrelated disease	6 (8.2)	5 (8.8)
CT for liver cirrhosis	10 (13.7)	9 (15.8)
Angiography for liver cirrhosis	8 (11.0)	4 (7.0)
Lipiodol-CT	2 (2.7)	2 (3.5)
Total	73 (100.0)	57 (100.0)[a]

[a] In 10 patients, one or two tumours were detected by one method; however, additional tumours were detected by other methods.

Diasonics SPA 1000 machines. Depending on patient size, 3.5 or 5.0 MHz transducers were used. Scans were generally performed across the entire upper abdomen in both transverse and sagittal planes.

Computed tomography was performed with a 9800 or 8800 scanner (General Electric) or equivalent third-generation scanner. Sections through the upper abdomen were made by use of 10 mm collimation at 10 mm contiguous intervals. Oral administration of diluted contrast medium and intravenous infusion of contrast medium were used in all patients. In most cases contrast medium was given by bolus injection of 120 ml of ioxithalamate meglumine (Telebrix 30, Guerbet).

Selective coeliac or common hepatic angiography was performed in all 47 patients. After angiography, 5–10 ml of Lipiodol mixed with chemotherapeutic agents was dripped via a catheter whose tip was advanced into the proper hepatic artery (39 patients), the common hepatic artery (three patients) or selectively into the right or left hepatic artery (five patients). Anticancer drugs mixed with Lipiodol were doxorubicin hydrochloride (Adriamycin, Adria) and mitomycin-C. Lipiodol/anticancer drug emulsion was prepared by mixing 5–10 ml of Lipiodol and 20–30 mg of doxorubicin and 6–10 mg of mitomycin-C in 2–3 ml of 60% ioxithalamate meglumine in syringes by the pumping technique. Lipiodol-CT was performed 1–3 weeks after this procedure with the same CT scanner and the same technique.

The sensitivity of sonography and CT were evaluated separately from an initial screening study, not from a detailed study. The sensitivity of angiography and Lipiodol-CT were evaluated from a second, more detailed study, performed using information gathered from other methods.

Results

Of the 47 patients with small HCCs, 31 had one tumour, 12 had two tumours and four had three tumours or more. The diameters of the tumours were as follows: <20 mm (27), 21–30 mm (20) and 31–50 mm (26). The tumour was located in the anterior segment of the right hepatic lobe in 27 cases, the posterior segment of the right hepatic lobe in 36, the medial segment of the left hepatic lobe in five, the lateral segment of the left hepatic lobe in four and the caudate lobe in one case.

The imaging methods that first led to the detection of small HCCs are summarized in Table I. Forty-seven tumours were detected by sonography on periodic check-up of patients with liver cirrhosis or abnormal liver function tests. Six tumours were detected incidentally by sonography in five patients being investigated for other reasons. Ten tumours were initially detected on CT scans of patients with liver cirrhosis. Lipiodol-CT detected two tumours that could not be detected by other methods. Sonography was the first imaging method for tumour detection in 53 tumours (72.6%). In 10 patients, one or two tumours were detected by one method, but additional tumours were detected by other methods (Table I).

The overall detection rates of small HCCs by sonography, CT, angiography and Lipiodol-CT are summarized in Table II. The results obtained on screening studies showed sonography to be slightly less sensitive than screening CT but there was no statistically significant difference between them. However, Lipiodol-CT was superior to sonography ($p<0.01$), CT ($p<0.01$) and angiography ($p<0.05$) in detecting small HCCs. On sonography, most undetected tumours were located in the right upper liver near the right diaphragm. The mean diameter of undetected tumours (2.1 ± 1.2 cm) was smaller than the tumours detected on sonography (3.1 ± 1.1 cm); two were isoechoic masses. On CT scans, contrast-enhanced CT was superior to non-contrast-

Table II. Detectability of small HCC by four imaging techniques

Tumour size (cm)	Number of tumours	Sonography (%)	CT			Angiography (%)	Lipiodol-CT (%)
			Non-contrast enhanced (%)	Contrast-enhanced (%)	Overall (%)		
$\leqslant 2$	27	14 (52)	6 (22)	15 (56)	15 (56)	20 (74)	25 (93)
$\leqslant 3$	20	17 (85)	12 (60)	20 (100)	20 (100)	18 (90)	20 (100)
$\leqslant 5$	26	22 (85)	19 (73)	25 (96)	25 (96)	25 (96)	25 (96)
Total (%)	73 (100)	53 (73)	37 (51)	60 (82)	60 (82)	63 (86)	70 (96)

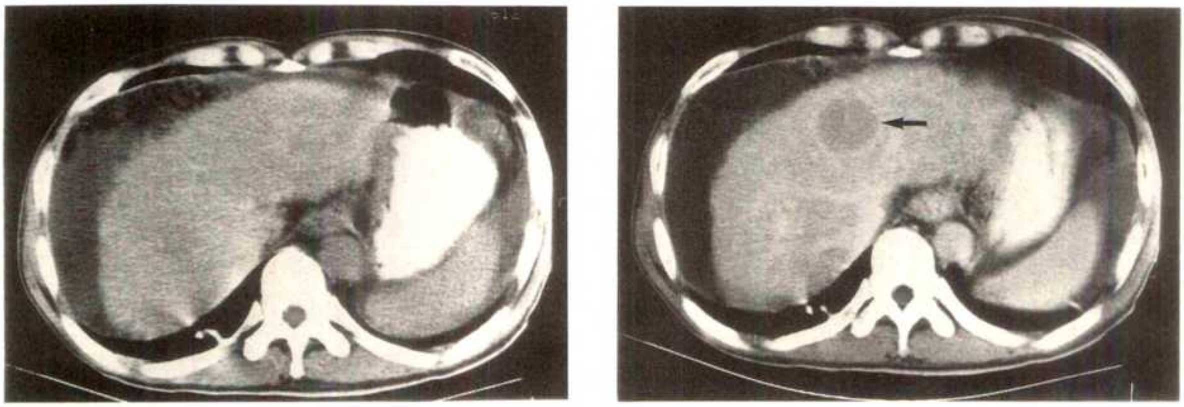
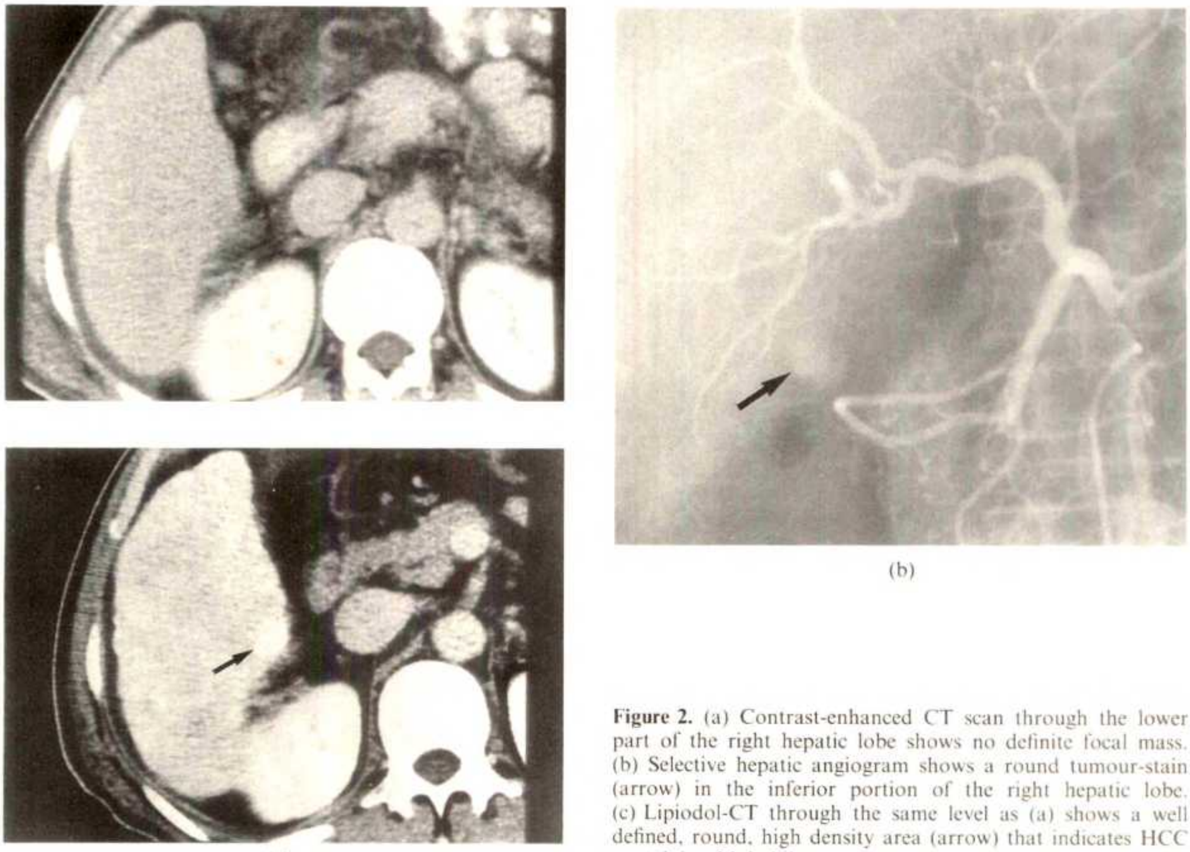

(a) (b)

Figure 1. (a) Non-contrast-enhanced CT scan through the upper portion of the liver shows no definite focal mass in the liver. Nodular contour of the liver surface, ascites and splenomegaly are seen, suggesting underlying liver cirrhosis. (b) Contrast-enhanced CT scan through the same level as (a) shows a well defined, round, low-density tumour with peripheral rim enhancement (arrow) in the medial segment of the left lobe.

enhanced CT in detecting small HCCs ($p<0.01$) (Fig. 1). Overall detection rate of CT was the same as that of contrast-enhanced CT. Eight of 13 undetected tumours on CT scans were located in the hepatic dome near the right diaphragm or porta hepatis. Three of them were isodense masses (Fig. 2). On angiography, four of 10 undetected tumours were small masses, which were located in the peripheral portion of the liver


(b)

(c)

Figure 2. (a) Contrast-enhanced CT scan through the lower part of the right hepatic lobe shows no definite focal mass. (b) Selective hepatic angiogram shows a round tumour-stain (arrow) in the inferior portion of the right hepatic lobe. (c) Lipiodol-CT through the same level as (a) shows a well defined, round, high density area (arrow) that indicates HCC containing Lipiodol.

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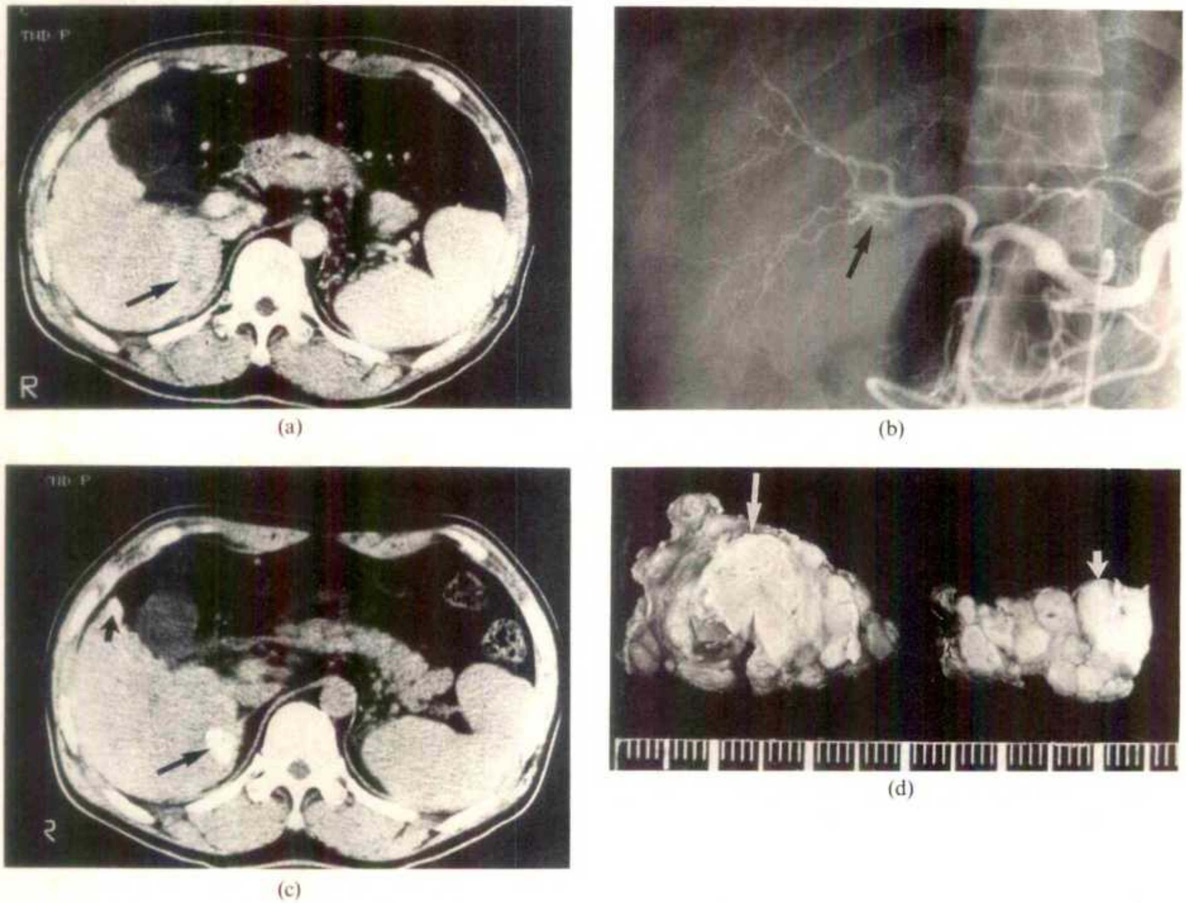

(a) (b) (c) (d)

Figure 3. (a) Contrast-enhanced CT scan through the right liver shows an ovoid, low-density tumour (arrow) in the posterior segment. (b) Coeliac angiogram shows an ovoid tumour stain (arrow) in the right hepatic lobe. (c) Lipiodol-CT through the same level as (a) shows a well defined, high-density area (arrow) that indicates HCC containing Lipiodol. Another small, well defined mass containing Lipiodol (short arrow), which cannot be detected on conventional CT or angiography, is clearly seen. (d) Resected specimens of the liver show two tumours (arrow and short arrow).

(Fig. 3) and eight of them were hypovascular (Fig. 4). On Lipiodol-CT, one of the undetected tumours was of small mass, measuring 1 cm in diameter. Two of them were hypovascular lesions that did not retain Lipiodol (Fig. 4c).

Discussion

Recent development of imaging techniques has made it possible to diagnose small, asymptomatic HCCs and the definition of "small HCCs" has had to be changed. In 1977, Okuda et al used the term "minute" HCC, which was defined as a solitary tumour smaller than 4.5 cm or a few tumour nodules smaller than 3.5 cm in diameter. In 1982, Chen et al described the term "small" HCC to denote a tumour smaller than 3.0 cm in diameter. The current criterion set by the Japanese Liver Cancer Study Group for designating small HCC is a single tumour less than 2 cm in diameter (Liver Cancer Study Group of Japan, 1983). However, other investigators (Takashima et al, 1982; Inamoto et al, 1983; Shinagawa et al, 1984; Kudo et al, 1986; Takayasu et al, 1986) defined "small" HCC as a tumour less than 5 cm in diameter, as in our definition, because detection of a lesion less than 2 cm is still difficult and the majority of focal tumours eligible for resection are larger than 2 cm in diameter.

Hepatocellular carcinomas frequently appear in association with chronic liver disease and the HBsAg carrier state (Beasley et al, 1981), as in our series. The follow-up period before detection of HCC is shorter in patients positive for HBsAg than in those negative for HBsAg (Kubo et al, 1978). In addition, small HCCs discovered by a mass screening programme have a very good prognosis when successfully resected. Therefore, periodic follow-up of high-risk patients by imaging techniques or other methods is essential for the early detection of HCCs.

There are several useful methods of detection. Serum

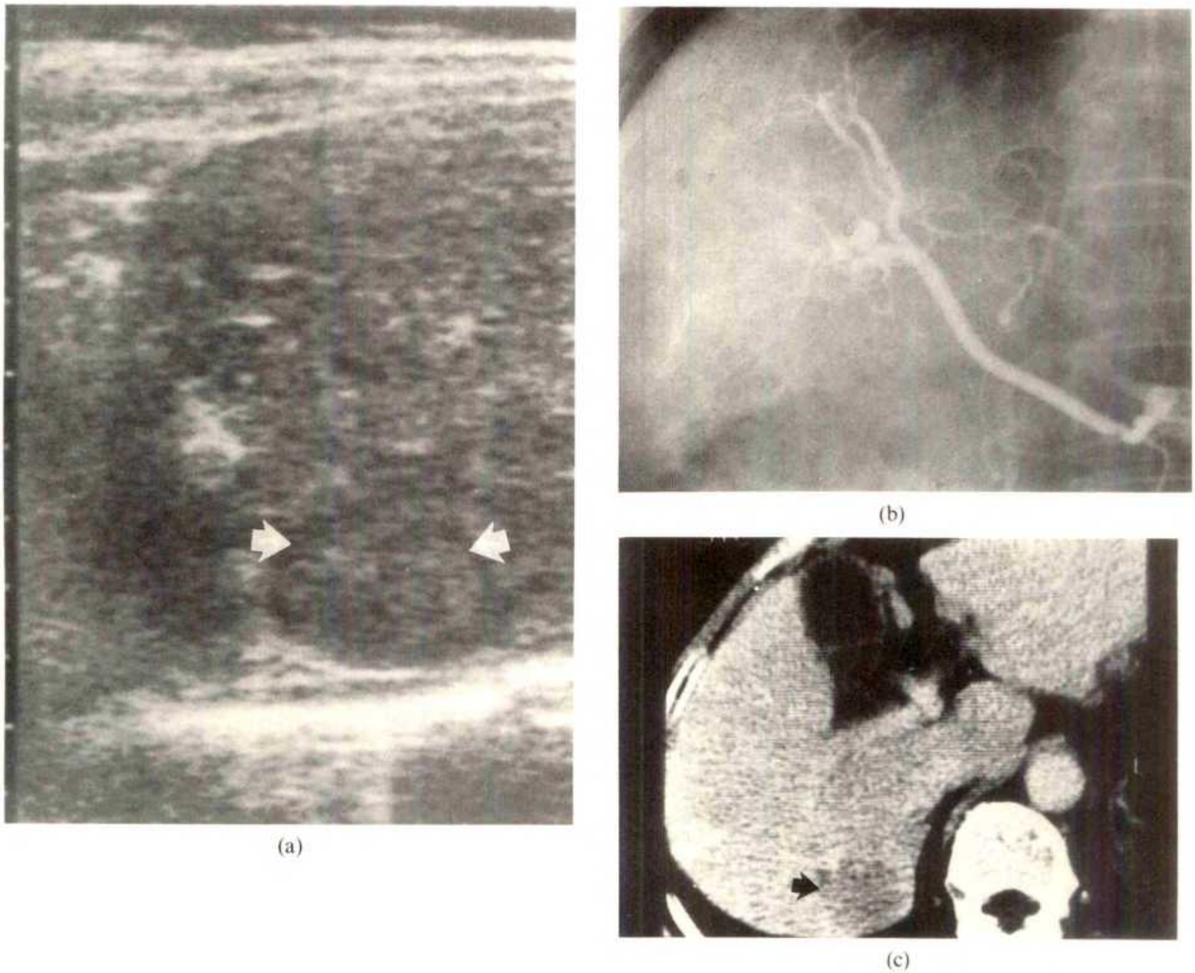
(a) (b) (c)

Figure 4. (a) Transverse sonogram of the liver shows a slightly hypoechoic mass with a peripheral hypoechoic halo (arrows) in the posterior segment of the right hepatic lobe. (b) Selective hepatic angiogram shows no definite hypervascular tumour in the liver. (c) Lipiodol-CT of the liver shows a round tumour with low density (arrow) in the posterior segment of the right hepatic lobe. However, there is no evidence of retention of Lipiodol in the tumour.

AFP assay can be used, but recent studies performed on patients with small HCCs show that the positive detection rate is low (Shinagawa et al, 1984; Sheu et al, 1985).

The high sensitivity of real-time sonography for detection of small HCCs has been established (Sheu et al, 1985; Kudo et al, 1986). In our series, sonography was the first imaging technique for tumour detection in 72.6%. As real-time sonography is simple, non-invasive and sensitive, it may be the procedure of choice for screening of small HCCs, especially in high-risk patients. However, there are several drawbacks. One major difficulty with real-time sonography, particularly with a linear transducer, is the detection of small lesions in the right hepatic lobe immediately below the diaphragm where lung air interference is great. Unfortunately, according to Takayasu et al (1986), small HCCs are located most frequently in the antero-superior subsegment of the right hepatic lobe. In our series, 12 of 20 cases in which sonography could not detect the lesion were located in the antero-superior portion of the right hepatic lobe. In isoechoic HCC, the tumour may easily be missed on sonography, and care must be taken in looking for hypoechoic halo representing the capsule and lateral shadow. This technique also frequently detects false positive or benign lesions and careful differential diagnosis is required (Choi et al, 1989).

Computed tomography has been suggested as an accurate method for the detection of small HCC, particularly when used with dynamic CT studies (Inamoto et al, 1983). It does not require skill in the examiner and can not only define more accurately the extent of the HCC, but it can also better define extrahepatic spread of disease (LaBerge et al, 1984). Detectability of small HCC by CT in our data is superior to that of previous reports (Takashima et al, 1982; Matsui et al, 1985; Kudo et al, 1986) because of a more modern machine and bolus injection of a large amount of contrast medium. Detectability of small HCCs on CT scans will vary depending on the X-ray attenuation of the lesion, which is influenced by the efficacy of the machine. Contrast enhancement contributes to decreased error in diagnosing tiny lesions. In our series, contrast-enhanced CT was superior to non-contrast-enhanced CT in identifying small HCCs, detecting 82% in comparison with 51% by non-contrast-enhanced CT. The significance of difference for non-contrast- and contrast-enhanced CT was $p < 0.01$. Sonographic and CT results in the detection of small HCCs were not significantly different ($p > 0.05$). However, CT can cover the "blind spot" of sonography and it was the first imaging technique for tumour detection in 10 cases (13.7%) of our series. The shortcomings of CT are partial volume effect caused by overlapping of surrounding structures and the blind area of the interslice gap. A small tumour may be invisible by minimal attenuation difference between the lesion and the surrounding liver parenchyma. Another weakness of CT lies with isodense tumours. Three of 11 undetected cases on CT scans were isodense tumours in our series.

Angiography gives a pre-operative vascular road map, and is an adjunct for assessing the extent of intrahepatic disease. As well as serving as a preliminary in the treatment of HCC (chemoembolization), angiography has high sensitivity in the detection of small HCCs because of their hypervascularity. Our data (86%) in this respect were comparable with others (Shinagawa et al, 1984; Takayasu et al, 1986). Pitfalls of angiography occur in the detection of small tumours and those of poor vascularity. Confusion can also occur when two masses are superimposed in the ventrodorsal direction.

Infusion of Lipiodol at angiography is a new technique. It was introduced for the treatment of HCC, since Lipiodol accumulates in a tumour and can be combined with lipophilic anticancerous agents (Iwai et al, 1984; Takayasu et al, 1987). It has also been reported that CT after Lipiodol infusion is useful in the detection of small hepatic nodules (Ohishi et al, 1985). Our study indicates that Lipiodol-CT is the most sensitive method in detecting small HCCs and requires less interpretative skill than detection with angiography because there is high contrast on CT scans between tumour containing Lipiodol and the liver parenchyma. Therefore, CT scans could identify more nodules when located behind the main tumour or very small in size. In three of our cases, tumour was not identified with Lipiodol-CT. One of them was detected on sonography and two were detected on plain CT scans; however, there was no evidence of Lipiodol retention in the tumours on Lipiodol-CT scans. We believe hypovascular or avascular HCC may be responsible for these false negative results. When the lesion was of such poor vascularity, Lipiodol could not reach the tumour.

Lipiodol-CT has additional benefit in differentiating small HCC from regenerating nodules. In the severely cirrhotic liver, small HCC (particularly less than 1 cm) and regenerating nodules show similar findings on sonography and conventional CT scans. On Lipiodol-CT, small HCC can usually retain Lipiodol while regenerating nodules do not (Yumoto et al, 1985).

Recently, transhepatic arterial embolization using Lipiodol mixed with anticancer drugs has been widely performed in inoperable cases and even in operable ones before surgery (Takayasu et al, 1987). The mechanism of chemoembolization of HCC is that the liver receives a dual blood supply from the hepatic artery and portal vein, whereas HCC is fed only by the hepatic artery (Breedis & Young, 1954) and embolization of the hepatic artery can be expected to result in selective ischaemic necrosis of the tumour tissue. The rationale of pre-operative chemoembolization of HCC is to reduce tumour size, improve operability, and prevent dissemination of cancer cells during the operation. Moreover, hepatic surgery itself has also been improved. The presence of liver cirrhosis alone or multiplicity of tumours is no longer a contraindication to hepatic resection. Multiple small HCCs that are located in the same hepatic lobes and HCC associated with mild liver cirrhosis (Child's class A), can be candidates for hepatic resection. Therefore, complete evaluation of HCC, including detection of all tumours and determination of their extent, is essential in the treatment of patients with HCC. In 10 patients (21.3%) of our series, tumours were detected by one method alone; however, additional tumours were detected by other methods, indicating the necessity of the combined use of multiple imaging techniques.

Currently in our hospital, we use AFP measurement and sonography as screening procedures for detecting small HCC in high-risk patients. If both examinations fail to demonstrate HCC, we recommend CT scans. Where a tumour is detected on sonography or CT, or in the case of highly suspicious liver cirrhosis without evidence of mass on sonography or CT, we perform angiography, not only for complementary work-up of the patient with liver cirrhosis, but also for Lipiodol-CT. On the basis of our experience, Lipiodol-CT often gives us the added information that is the determining factor in defining the patients who will benefit from transhepatic arterial embolization and those better treated with surgical intervention. In summary, we believe that combined use of multiple imaging techniques including Lipiodol-CT is mandatory in detecting and evaluating small HCCs.

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Alterations in body and skin temperatures caused by magnetic resonance imaging: is the recommended exposure for radiofrequency radiation too conservative?

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Abstract. Increases in tissue temperature caused by exposure to radiofrequency (RF) radiation are a primary safety concern of magnetic resonance imaging (MRI). Therefore, body and skin temperatures were measured in six subjects before (20 min), during (30 min) and after (20 min) MRI procedures performed at specific absorption rates (SARs) six to 10 times higher than the limit recommended by the UK National Radiological Protection Board. Body temperature was unchanged throughout the experiment. Abdominal skin temperature increased significantly ($p<0.05$) during MRI, decreased significantly post-MRI, but was still significantly ($p<0.05$) higher than baseline. The highest abdominal skin temperature recorded was 36°C. Upper arm, forearm and chest skin temperatures increased significantly ($p<0.05$) during MRI and remained elevated post-MRI. The highest skin temperatures recorded on the upper arm, forearm and chest were 38.1, 36.0 and 34.5°C, respectively. Thigh and calf skin temperatures were not significantly changed during MRI. These alterations in tissue temperatures were physiologically trivial and easily tolerated by the subjects, suggesting that the recommended exposure to RF radiation during MRI of the body for patients with normal thermoregulatory function may be too conservative.

Tissue heating is the primary biological effect of radiofrequency (RF) radiation (Shellock et al, 1986; Kido et al, 1987; Shellock, 1987; Shellock & Crues, 1988a,b). Therefore, the UK National Radiological Protection Board (NRPB) has recommended that the acceptable limit of exposure to RF energy during clinical magnetic resonance imaging (MRI) "should not result in a rise in body temperature of more than 1°C as shown by skin and rectal temperature" (NRPB, 1983). It was presumed that this temperature change would be ensured by limiting the exposure to RF radiation to a mean (*i.e.* whole-body average) specific absorption rate (SAR) of 0.4 W/kg (NRPB, 1983).

Since the publication of the NRPB guidelines in 1983, a number of investigations have been performed to examine temperature responses in patients undergoing MRI at exposures to RF radiation above mean SARs of 0.4 W/kg (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987). Although there were statistically significant increases in body and skin temperatures reported in these studies, none of these temperature elevations were physiologically deleterious (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987), suggesting that the NRPB guidelines for exposure to RF radiation during MRI may be too conservative. A limitation of these previous studies was that temperature measurements were obtained before and after the imaging procedures (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987) because of the inherent problems associated with recording physiological variables (especially temperature) during the operation of the MR scanner (Reis, 1979; NCRP, 1981; Shellock, 1986). Consequently, any excessive elevations in tissue temperatures that may have occurred in the course of MRI would not have been detected.

Technological advances in thermometry have recently produced a fibre-optic-based device that permits continuous monitoring of temperature, unperturbed by electromagnetic radiation (Wickersheim & Sun, 1987). In this paper we report the use of this fluoroptic thermometry system to determine body and skin temperature responses before, during and after MRI of human subjects exposed to mean SARs six to 10 times higher (*i.e.* up to 4.0 W/kg) than the level recommended by the NRPB. In consideration of the data obtained from this investigation, as well as the results from prior clinical studies, the appropriateness of the acceptable limit for exposure to RF radiation during clinical MRI of the body is discussed.

Methods

Six normal males were studied under a protocol approved by the Institutional Review Board. Table I lists pertinent data for these subjects. The subjects were thoroughly screened before the procedure (*i.e.* no pacemakers, aneurysm clips, etc.) to determine that they could safely undergo MRI.

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Table I. Age, sex, body weight and mean specific absorption rate for the study subjects

Subject	Age (years)	Sex	Body weight (kg)	Mean SAR (W/kg)
1	37	M	69.0	2.8
2	29	M	77.0	3.6
3	25	M	74.5	3.6
4	25	M	90.5	2.7
5	38	M	81.0	3.4
6	31	M	61.0	4.0

Magnetic resonance imaging was performed using a 1.5 T superconducting magnet operating at 64 MHz for proton imaging (Signa MR system, General Electric Company) with a circularly polarized transmit/receive RF body coil. This RF coil is 55 cm in diameter and 55 cm in length. Each subject was positioned in the MR scanner such that the subject's umbilicus was at the centre of this coil. The mean specific absorption rates (SAR) were determined using standard measurements and calculations (Bottomley & Edelstein, 1981; Bottomley et al, 1985; NCRP, 1981; see also Appendix I) and are listed for each subject in Table I. Various mean SARs were studied in this experiment in order to evaluate responses to a range of increasing values up to a maximum of 4.0 W/kg.

A fluoroptic thermometry system (Model 3000, Luxtron) was used to measure temperatures (Wickersheim & Sun, 1987). This device has an accuracy and resolution of ±0.1°C. The calibration was checked before each experiment using the procedure recommended by the manufacturer. Body temperature was measured by placing the fluoroptic probe in the sublingual pocket (the portion of the oral cavity that has the warmest and most stable temperature, located near the vasculature at the joint of the tongue and the base of the floor of the mouth) of the subject. This site has been previously demonstrated to provide a good indication of internal body temperature (Gerbrandy et al, 1954; Bligh, 1973; Houdas & Ring, 1982). The subject's mouth was taped shut around the fibre-optic cable so that the temperature would be unaffected by mouth breathing and to ensure proper positioning of the probe throughout the experiment. Skin temperatures were measured by attaching the tip of the temperature probe to the skin surface with a 3 cm × 4 cm piece of Micropore tape (3M). Skin temperatures were recorded from the following sites: abdomen, upper arm, forearm, chest, thigh and calf.

Since increasing blood flow to the cutaneous vascular bed is an important effector of heat dissipation, cutaneous blood flow was measured in each subject using the non-invasive, laser-Doppler velocimetry technique (Stern et al, 1977). A Laserflo blood perfusion monitor (Model 403, TSI, Inc.) was used for this measurement. This instrument has an accuracy and resolution of ±10%. A 1.5 cm diameter, circular, plastic flow probe was fixed to the skin area 1 cm above the umbilicus of the subject using a perforated, double-sided adhesive disc. This site (*i.e.* landmarked position for MRI) was selected for monitoring cutaneous blood flow because it was the area that received the highest deposition of RF power (Bottomley & Edelstein, 1981; Bottomley et al, 1985; Shellock & Crues, 1987).

Experimental protocol

Study subjects wore lightweight cotton shorts and had a similar amount of skin surface area uncovered during the procedure. The ambient conditions were: room temperature 21.0 ± 1.0°C, relative humidity 45% and air flow <0.1 m/s. Baseline measurements were obtained with the subjects inside the MR scanner for 20 min. Magnetic resonance imaging was then performed for 30 min, followed by 20 min without MRI. Body and skin temperatures were recorded at 1 min intervals throughout the above-mentioned time periods. Cutaneous blood flow was measured during the last minute of baseline, MRI and post-MRI.

Statistical analysis

In order to determine statistical differences, variables obtained at the 20th min of the baseline period, at the 30th min of MRI and at the 20th min of post-MRI were compared using a one-way analysis of variance for repeated measures (Winer, 1971). If the overall analysis of variance showed statistical significance ($p<0.05$), the data were further analysed using a multiple comparison test.

Results

Figure 1 displays the body and skin temperatures recorded in a subject exposed to a mean SAR of 2.8 W/kg. These data were selected for display because this subject exhibited some of the larger changes in skin temperatures associated with MRI. For this subject, body temperature was essentially unchanged during the experiment. Skin temperatures recorded on the abdomen, upper arm, forearm and chest began to increase within the first 10 min of MRI and were the highest either at the completion of MRI or during the first 3 min post-MRI. Only slight changes that were not statistically significant were noted for the thigh and calf skin temperatures.

Table II displays the mean values for cutaneous blood flow, body and skin temperatures recorded in this study. There was a statistically significant ($p<0.05$) increase in cutaneous blood flow at the 30th min of MRI that decreased back to the baseline level at the 20th min post-MRI.

There were no statistically significant differences in any of the mean body temperatures during the experiment. Body temperature changes associated with MRI were as follows: unchanged in four of the subjects (mean SARs: 2.7, 2.8, 3.6 and 3.6 W/kg), increased 0.1°C in one of the subjects (mean SAR 4.0 W/kg) and increased 0.2°C in one of the subjects (mean SAR 3.4 W/kg).

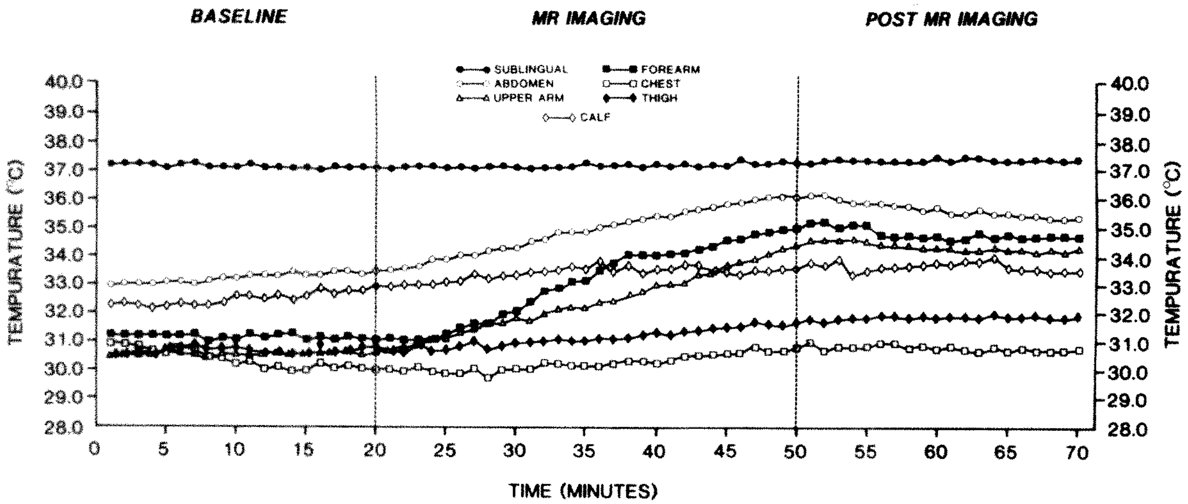

Figure 1. Typical example of body and skin temperatures recorded in Subject 1 during a 20 min baseline period, MRI performed for 30 min at a mean SAR of 2.8 W/kg, and during a 20 min post-MRI period.

The mean skin temperature of the abdomen increased significantly ($p<0.05$) at the 30th min of MRI, decreased significantly at the 20th min post-MRI but was still significantly ($p<0.05$) higher than baseline during this time. The highest abdominal skin temperature recorded was 36°C and the largest temperature change was 3.9°C.

Mean skin temperatures of the upper arm, forearm and chest increased significantly ($p<0.05$) at the 30th min of MRI, remained elevated at the 20th min post-MRI and were significantly ($p<0.05$) higher than baseline. The highest skin temperatures recorded on the upper arm, forearm and chest were 38.1, 36.0 and 34.5°C, respectively. The largest skin temperature changes measured at these sites were 7.5, 3.9 and 2.9°C, respectively. Mean skin temperatures of the thigh and calf were not significantly changed at the 30th min of MRI nor at the 20th min post-MRI.

All of the study subjects reported that they felt warm during the procedure and each of them had visible signs of perspiration on their foreheads, chest and abdomen. None of the study subjects reported feeling uncomfortable as a result of the temperature changes.

Discussion

Temperature sensitive neurons located in various parts of the body including the skin, hypothalamus, spinal cord, mid-brain and the visceral organs are responsible for detecting alterations in tissue temperatures and for activating the appropriate physiological response(s) to regulate internal body temperature (Bligh, 1973; Houdas & Ring, 1982; Gordon, 1984). During exposure to an external heat load, body and skin temperatures will increase once the capacity for heat loss by cutaneous vasodilation and sweating is overwhelmed by the amount of heat gained (Bligh, 1973; Houdas & Ring, 1982; Gordon, 1984).

The subjects undergoing MRI in this study had no change in mean body temperature and statistically significant increases in mean skin temperatures of the

Table II. Cutaneous blood flow, body and skin temperatures measured at baseline (at the 20th min), during MRI at an average mean SAR value of 3.4 ± 0.5 SD (at the 30th min) and post-MRI (at the 20th min)

	Baseline	MRI	Post-MRI
Cutaneous blood flow (ml/min/100 g)	1.00 ± 0.7^a	2.04 ± 1.1^b	1.46 ± 0.6
Body temperature (°C)	37.1 ± 0.4	37.2 ± 0.4	37.2 ± 0.4
Abdominal skin temperature (°C)	32.7 ± 1.4^a	34.9 ± 1.2^b	34.4 ± 1.1^c
Upper arm skin temperature (°C)	32.4 ± 1.6^a	35.6 ± 1.4	34.5 ± 1.4^c
Forearm skin temperature (°C)	32.0 ± 1.6^a	33.8 ± 1.0	33.5 ± 1.3^c
Chest skin temperature (°C)	31.1 ± 1.4^a	32.3 ± 1.8	31.8 ± 1.5^c
Thigh skin temperature (°C)	31.8 ± 1.0	32.7 ± 1.3	33.0 ± 1.1
Calf skin temperature (°C)	31.8 ± 1.4	31.6 ± 1.5	31.5 ± 1.3

Values given are mean ± standard deviation; $^a p < 0.05$, baseline compared with MRI; $^b p < 0.05$, MRI compared with post-MRI; $^c p < 0.05$, post-MRI compared with baseline.

upper body (*i.e.* abdomen, upper arm, forearm and chest). Since the mean body temperature was unchanged, the combination of increased cutaneous blood flow and sweating appear to have been adequate to control the body temperature of these healthy subjects, despite being exposed to relatively high levels of RF power.

The activation of these two heat loss mechanisms may be caused by either a direct effect of RF radiation-induced heating on the calibre of the arterioles and sweat glands or by an indirect, neurally mediated stimulation of the deep body thermal receptors (Gordon, 1984; NCRP, 1986). Of note is the fact that an increase in body temperature of as little as 0.1–0.2°C can activate the deep body thermal receptors (Houdas & Ring, 1982; Gordon, 1984). The statistically significant increase in abdominal cutaneous blood flow and sweating observed on the various skin surfaces (*i.e.* forehead, chest and abdomen) of the subjects in this study appears to be caused primarily by direct RF radiation-induced heating, since only two of the subjects had a change in body temperature within the range necessary to stimulate the deep body thermal receptors. However, for these two subjects, deep body thermal receptors may have been partially involved in the activation of their heat dissipation responses.

The data from this study support previous theoretical predictions (Bottomley & Edelstein, 1981; Bottomley et al, 1985) and clinical investigations (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987, 1988a,b) that showed MRI causes tissue heating that is primarily confined to surface tissues with little or no effect on internal body temperature. The RF power that is absorbed by the body during MRI is primarily magnetic with a negligible contribution from the electric field (Bottomley & Edelstein, 1981; Bottomley et al, 1985). Therefore, the ohmic heating that occurs is greatest at the surface of the body and approaches zero at the centre of the body. In addition, the highest temperature changes observed in this study occurred at the completion of MRI, demonstrating that it is sufficient to monitor temperatures immediately post-MRI when evaluating RF radiation-induced tissue heating in human subjects.

None of the temperatures recorded during this investigation were considered to be excessive (Bligh, 1973; Houdas & Ring, 1982; Gordon, 1984; NCRP, 1986). To put these temperature changes into proper perspective, it should be noted that both body and skin temperatures undergo regular diurnal variations. Body temperature follows a circadian rhythm and can vary by as much as 1.0°C, while skin temperature also changes by as much as 5–10°C, depending on the anatomical site (Bligh, 1973; Houdas & Ring, 1982). Furthermore, the temperature level at which painful sensations and damage occurs is between 43 and 45°C (Hardy et al, 1951). In consideration of all of the above, the temperature changes noted during this study were physiologically inconsequential.

Previous studies investigating temperature responses in patients during MRI at SARs >0.4 W/kg (up to 1.3 W/kg) indicated that there were statistically significant changes in body (temperature changes up to 0.6°C) and skin temperatures (temperature changes up to 3.5°C) (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987). In comparison with the normal subjects, the increased body temperatures noted in these clinical studies were probably caused by the fact that some of these patients had underlying health conditions (fever, diabetes, cardiovascular disease, obesity, etc.) or were taking medication (beta blockers, diuretics, vasodilators, etc.) that are known to impair thermoregulation (Kenny, 1985; Shellock & Crues, 1987). Despite the above, it was apparent that these patients could easily tolerate MRI at SARs that were two to three times higher than the limit recommended by the NRPB without any serious sequelae (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987). Therefore, data obtained in this investigation as well as the other clinical studies (Shellock et al, 1986; Kido et al, 1987; Shellock & Crues, 1987) suggest that the guidelines for exposure to RF radiation recommended by the NRPB may be too conservative, particularly for patients with normal thermoregulatory function.

The safety criteria of the NRPB (1983) specifying that MRI "should not result in a rise in body temperature of more than 1°C as shown by skin and rectal temperature" does not take into account important aspects of human temperature regulation (Bligh, 1973; Houdas & Ring, 1982; Gordon, 1984; NCRP, 1986). From a thermal tolerance standpoint, an increase of 1°C in skin temperature is relatively insignificant and does not compare with a 1°C increase in internal body temperature, considering that the temperature of the skin is lower and more labile than internal body temperature (Bligh, 1973; Houdas & Ring, 1982; Gordon, 1984; NCRP, 1986).

Furthermore, the stipulation of an acceptable body temperature as one being measured in the rectum should also be reconsidered since there is significant thermal inertia associated with this measurement site (Bligh, 1973; Houdas & Ring, 1982). Clearly, if internal body temperature is to be used as a safety criterion for MRI, a measurement site should be selected that is in close proximity to the body's temperature regulating centre (*i.e.* the hypothalamus) and that is capable of rapidly responding to acute changes in temperature. Locations of the body previously demonstrated to provide a good index of internal body temperature and that react promptly to temperature changes include the sublingual pocket, the tympanic membrane, the oesophagus and blood in the pulmonary artery (Gerbrandy et al, 1954; Bligh, 1973; Houdas & Ring, 1982; Shellock & Rubin, 1986).

In consideration of the results of this study as well as previously published data (Shellock et al, 1986; Kido et al, 1987; Shellock, 1987; Shellock & Crues, 1988a,b), it appears that primarily surface tissue heating is associated with MRI. However, since we and others have not measured deeper tissue temperatures, the possibility exists that tissues immediately under the skin could be heated during MRI and these temperature elevations may not be appreciated owing to evaporative surface cooling (*i.e.* sweating). Therefore, additional studies should be performed to determine the possible presence of deep tissue heating associated with MRI of human subjects. In addition, investigations should be conducted in patients with impaired thermoregulatory function (*i.e.* elderly patients, patients with underlying health conditions associated with heat intolerance such as fever, diabetes, cardiovascular disease or obesity, and patients taking medications that affect thermoregulation such as beta blockers, diuretics, vasodilators, etc.) to determine their temperature responses to MRI performed at high SARs.

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Appendix I

The peak forward radiofrequency (RF) power was adjusted to obtain the desired specific absorption rate (SAR) level in the volunteer. The explanation for how this was done follows. The RF was amplitude modulated by a series of low-frequency sinc pulses. A four-echo pulse sequence with a repetition time (TR) of 125 ms was selected to maximize the RF duty cycle. Note that the RF transmit level was adjusted to result in the desired SAR without regard to imaging considerations (although the level required for a 180° pulse was determined). Peak envelope detecting power meters (which sample the peak of the demodulated RF; Model 4391, Bird Electronic Corporation), accurate to within ±5% of full scale for the element selected, were used to measure the peak forward and reflected (typically very small owing to impedance matching) RF power levels. The peak load-diverted power was determined by measuring attenuator (dummy load) voltage on an oscilloscope (Fig. 2). These readings were adjusted for transmission line losses so that all peak power readings were referenced to the terminals of the RF coil (the transmitter was passively impedance matched to the coil so that there were no additional transmission lines losses created by standing waves). Given that the attenuation from the power meter to the splitter is α and from the dummy load to the oscilloscope is β, that the subscript c refers to measurements at the coil terminals, while no subscript refers to measurements made at the power meter, and P refers to peak power, then one may write:

$$P_{\text{forward}c} = P_{\text{forward}} \times \alpha \qquad (1)$$

$$P_{\text{reflected}c} = P_{\text{reflected}}/\alpha \qquad (2)$$

$$P_{\text{load}c} = P_{\text{load}}/\beta \qquad (3)$$

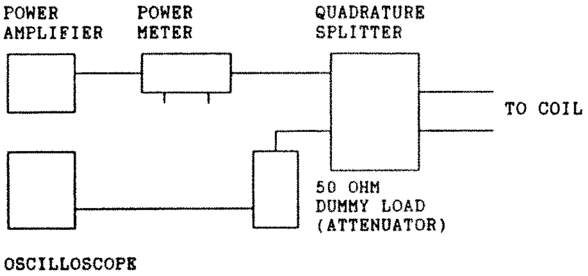

Figure 2. Power measurements on a Signa body coil.

Note that $P_{\mathrm{reflected}c}$ is typically nearly zero. Also, a reflection coefficient, Γ, may be defined as:

$$\Gamma^2 = P_{\mathrm{load}}/P_{\mathrm{forward}} \tag{4}$$

The net peak RF power absorption into the RF coil/volunteer combination was then calculated as the peak forward RF power at the terminals of the coil minus the peak reflected RF power at the coil minus the peak RF power diverted to the dummy load:

$$P_{\mathrm{coil/patient}} = P_{\mathrm{forward}c} - P_{\mathrm{reflected}c} - P_{\mathrm{load}c} \tag{5}$$

In order to distinguish how much power was absorbed by the volunteer as opposed to the power that was dissipated in various ways by the RF coil, an efficiency factor, ε, was calculated from coil losses and the patient/coil combination losses both measured at the same flip angle. Coil losses were determined by placing a small, lossless, copper sulphate bottle into the MR system and then peaking the power spectrum for maximum received signal. By measuring the forward, reflected and dummy-load diverted power levels (and correcting for transmission line losses), the net peak power absorbed by the phantom/coil combination may be calculated. It may be assumed that all dissipated power is lost in the RF coil owing to the small area and low conductivity of the phantom. The power absorbed by the volunteer alone in a separate experiment may then be calculated simply as:

$$P_{\mathrm{patient}c} = P_{\mathrm{coil/patient}c} - P_{\mathrm{coil}c} \tag{6}$$

The efficiency factor, ε, may be calculated for the coil as:

$$\begin{aligned}\varepsilon &= P_{\mathrm{patient}c}/P_{\mathrm{coil/patient}c}\\ &= 1-(P_{\mathrm{coil}c}/P_{\mathrm{coil/patient}c})\end{aligned} \tag{7}$$

The net peak power absorbed by the patient may be calculated as:

$$P_{\mathrm{patient}c} = P_{\mathrm{coil/patient}c} \times \varepsilon \tag{8}$$

Finally, the peak power data must be converted to an average power. The average power, P_{ave}, is found by summing the integrals of each power waveform, P_i, over time and dividing by TR:

$$P_{\mathrm{ave}} = \left(\sum_i \int P_i \,\mathrm{d}t\right)/\mathrm{TR} \tag{9}$$

For a given pulse sequence and coil, a constant, K, relates the average power to the peak power, P_{peak}:

$$P_{\mathrm{ave}} = K \times P_{\mathrm{peak}} \tag{10}$$

Whole-body SAR was calculated as the average RF power absorbed by the volunteer divided by the total body mass of the volunteer.

To summarize the method of obtaining the desired SAR in the volunteer, the measured peak forward power, (P_{forward}) was adjusted according to the mass of the volunteer (MASS), the desired SAR, the coil efficiency (ε), the power constant (K), the forward power transmission line attenuation (α), the load-diverted power transmission line attenuation (β), and the magnitude of the reflection coefficient Γ:

$$P_{\mathrm{forward}} = (\mathrm{SAR} \times \mathrm{MASS})/(\varepsilon \times K \times [\alpha - \{\Gamma^2/\beta\}]) \tag{11}$$

The forward peak power was adjusted in accordance with Equation 11 to obtain the desired SAR level.

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Enhanced risk from low-energy screen–film mammography X rays

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Abstract. Modern screen–film mammography with molybdenum-anode X rays results in tissue doses being delivered primarily by photons with an energy of <20 keV. Such photons interact with tissue predominantly through the photoelectric effect, producing low-energy electrons that have different patterns of energy deposition at the cellular level compared with those from higher-energy X rays. These differences result in low doses of typical molybdenum-based mammography X rays having an estimated radiobiological effectiveness of ~ 1.3 compared with 80 kVp or 250 kVp X rays, and ~ 2 compared with higher-energy γ rays. Thus the risk from mammography could be higher, by such factors, than previously estimated. This would result in the optimal age for beginning mammographic screening, derived from risk–benefit ratios, being increased by at least 1–2 years and possibly by as many as 10 years.

The use of screen–film mammography is desirable because of the decreased dose required to obtain comparable information, as compared with xeromammography (National Council on Radiation Protection and Measurements (NCRP), 1986). In order to obtain optimum tissue contrast, such examinations are typically performed using a 28 kV X-ray tube with a molybdenum target and 0.03 mm of molybdenum filtration. This system is used, for example, in the Swedish breast cancer screening programme (Tabar & Gad, 1981). The fluence spectrum produced by such a machine is shown in Fig. 1 (Dance, 1987).

It has been pointed out both on general biophysical grounds (International Commission on Radiation Units and Measurements (ICRU), 1986) and experimentally (*e.g.* Zeitz et al, 1977 [cell survival in HeLa cells]; Virsik et al, 1981 [chromosome aberrations in human lymphocytes]; Arslan et al, 1986 [cell survival and chromosome aberrations in hamster cells]; Bistrovic et al, 1986 [cell survival of V79 cells]; Hoshi et al, 1988 [cell survival of V79 cells]) that photons with energies below ~ 30 keV have an enhanced biological effectiveness because of the different mode of interaction with tissue compared with higher-energy X rays. In this paper we investigate the significance of this effect on mammographic screening recommendations.

Methods

As the energy of the photon decreases, so its mode of interaction with tissue changes. At, say, 100 keV, photons interact with tissue almost entirely through Compton scattering, but at energies less than ~ 30 keV, absorption through the photoelectric effect dominates. These photoelectric interactions produce a higher proportion of lower-energy secondary electrons, which in turn lead to different patterns of energy deposition at the microscopic or cellular level. The difference in energy-deposition characteristics is illustrated in Fig. 2, which shows the lineal energy (y) deposition spectra for different-energy photons. These spectra represent measured distributions of single-event energy depositions (per unit path length) produced by monoenergetic photons in a 1 μm sphere of unit density. The spectrum for low-energy photon interactions is shifted to considerably higher lineal energies.

At low doses, the energy distribution patterns in individual cells, as shown in Fig. 2, determine the relative biological effect. Such a situation follows if the initial lesion for cancer induction is related to energy deposition in a single cell, a notion supported by the known monoclonal origin of many cancers, *including* breast cancer (*e.g.* Lundberg et al, 1987). In terms of the relative effects of different radiations, all that changes from radiation to radiation, for a given dose, is the distribution of energy deposited in target cells—which is exactly the information in Fig. 2. For a given low dose, it can be shown (Zaider & Brenner, 1985; ICRU, 1986) that the response R (per unit dose) of a biological system to a given radiation i can be written:

$$R_i = \int r(y) d_i(y)\,\mathrm{d}y \qquad (1)$$

where $d_i(y)$ is the normalized distribution of dose in lineal energy for radiation type i (see Fig. 2), and $r(y)$ is the relative effect as a function of lineal energy. In other words, cells respond with a response function $r(y)$ (independent of the radiation, but characteristic of the end-point) to a range of energy depositions $d_i(y)$ (independent of the end-point but characteristic of the radiation) producing a total response R_i.

Equation 1 applies only to low doses where individual cells are subject to, on average, much less than one energy deposition event. This condition—implying a linear dose response—is obtained in the dose range of interest in mammography. In fact, Equation 1 is valid for predicting relative biological effects at low doses even if the mechanism of cancer induction involves

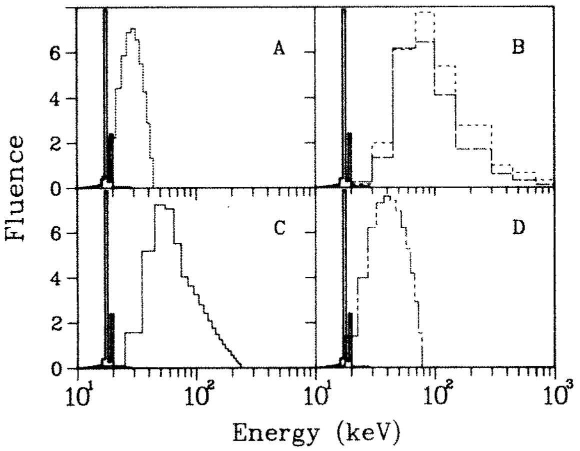

Figure 1. Fluence distributions, per unit energy, for the various photon fields considered in this paper. For comparison, the low-energy spectrum of 28 kVp X rays from a molybdenum target (Dance, 1987) is shown in each graph. The other spectra shown, which are all arbitrarily normalized, are: (A) 44 kVp X rays from a tungsten target, typical of those used in xeromammography (Dance, 1987); (B) spectra incident on survivors at Hiroshima (short dashes) and Nagasaki (long dashes). The ground distances from the explosions were, respectively, 1546 and 1919 m (data courtesy of Dr W. Woolson, Science Applications Inc.); (C) 250 kVp X rays from a tungsten target, typical of those delivered to Rochester acute post-partum mastitis patients (Stanton et al, 1979); and (D) 80 kVp X rays from a tungsten target, typical of those used in fluoroscopic examinations during pneumothorax therapy given to Massachusetts tuberculosis patients (Stanton et al, 1979).

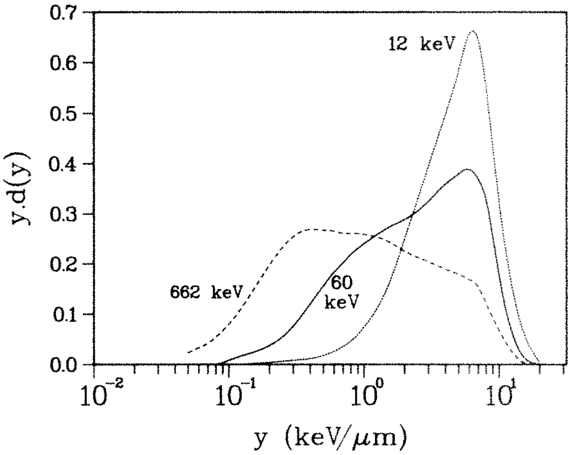

Figure 2. Typical lineal energy (y) distributions for different-energy photons. Plotted here is the distribution of dose deposited at different lineal energies in a 1 μm sphere. Each spectrum is normalized to unit absorbed dose. Data derived from Kliauga and Dvorak (1978).

interaction between autonomous cells, or promoting factors, as long as these processes are independent of radiation quality.

The function $r(y)$ in Equation 1 is identical to the so-called quality factor $Q(y)$, described in ICRU Report 40 (ICRU, 1986). Although $Q(y)$ was derived from data for chromosome-aberration formation in human lymphocytes, it is suggested that it is representative of such a function for a variety of end-points. As an example, this ICRU $Q(y)$ function, when used with Equation 1, has been shown by Miller et al (1989) to be predictive of the relative biological effectiveness for *in vitro* oncogenic transformation by different-energy neutrons. Therefore, we shall estimate the relative effectiveness R of molybdenum X rays by folding the response function $r(y)$ taken from ICRU Report 40, with a calculated energy deposition function, $d(y)$, appropriate for molybdenum X rays.

Estimation of effectiveness of different photon spectra

The function $d(y)$, the lineal energy deposition distribution in dose, for a polyenergetic photon field can be related to the energy-deposition characteristics of monoenergetic photons by the following equation (Goodhead & Brenner, 1983):

$$d(y) = \int EN(E)\mu_{en}(E)/\rho \, d(y;E)\,\mathrm{d}E \qquad (2)$$

where $N(E)$ is the fluence of photons at energy E, $\mu_{en}(E)/\rho$ is the mass-energy absorption coefficient at energy E, and $d(y;E)$ is the normalized spectrum of lineal-energy depositions for monoenergetic photons of energy E.

The spectra $d(y;E)$ for monoenergetic photons were taken from the measurements of Kliauga and Dvorak (1978) in a 1 μm equivalent-diameter wall-less proportional counter, which encompasses data for 12, 25, 36, 60, 140, 320, 662 and 1250 keV photons. Sample spectra are shown in Fig. 2. Interpolation between photon energies was achieved using a two-dimensional interpolation scheme described by Akima (1978).

The initial fluence spectrum, $N(E)$, emerging from a molybdenum-based X-ray machine, was derived from the measurements of Dance (1987), as shown in Fig. 1. A more relevant fluence spectrum for our purposes, however, would be that at the breast midplane, in the glandular region (NCRP, 1986). For this reason, a Monte Carlo simulation was performed to transport the photons from the X-ray source to the breast, and through the breast. A 0.45 m target–surface distance was used, and the breast was assumed to be compressed into a right-cylindrical shape with length 0.06 m and cross-section a semicircle of area 0.0093 m^2 (Hammerstein et al, 1979). The composition of the breast was assumed to be equal parts by weight of water and fat with density 0.96 gm/cm^3 (White et al, 1977). The fluence was estimated crossing a plane normal to the beam at a depth of 0.03 m. The photon transport was accomplished using the Monte Carlo computer transport code MCNP (Briesmeister, 1986) running on a Cray X-MP computer. Updated photon-interaction cross-sections recently published by Saloman et al (1988) were used in the calculations. The transport of 2×10^6 photons was carried out, ensuring a statistical uncertainty in the estimated fluence spectrum of no

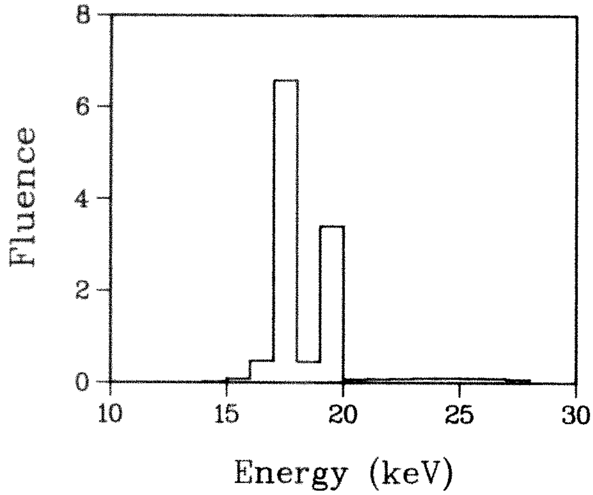

Figure 3. Calculated fluence distribution per unit energy from molybdenum-based 28 kVp X rays at a 0.03 m depth in the breast (see text for details).

more than 2% in each 1 keV wide energy bin. The results are shown in Fig. 3.

Using this calculated fluence spectrum, $N(E)$, the relative effectiveness R of the radiation was calculated using Equations 1 and 2, with $\mu_{en}(E)$ taken from Saloman et al (1988) and Hubbell (1982), and $r(y)$ from ICRU Report 40 (ICRU, 1986).

For purposes of comparison, R was also calculated for a 44 kVp beam (tungsten target, commonly used in xeromammography), an 80 kVp beam (typical of those used in fluoroscopic examinations during pneumothorax therapy for tuberculosis), a 250 kVp beam (typical of those used in mastitis therapy), and for the photon spectra incident on the breast of female survivors at Hiroshima and Nagasaki. The spectra used are shown in Fig. 1. All the spectra were transported through the breast, to find the midplane fluence, though the changes observed in all cases (except the molybdenum X-ray spectrum) were small. In the calculations of the lineal-energy spectra at Hiroshima and Nagasaki, where there were significant numbers of high-energy photons, it was assumed that the lineal-energy spectrum $d(y;E)$ does not change significantly as the photon energy increases from 1.2 to 10 MeV (Amols & Kliauga, 1985).

Results and discussion

The relative effectiveness of the six photon beams discussed above are shown in Table I, as estimated from Equations 1 and 2. The response function $r(y)$, taken from ICRU 40 (ICRU, 1986), is itself normalized such that the effectiveness of 100 keV photons is unity. The spectra for 250, 80 and 44 kVp X rays produce relative effectivenesses insignificantly different from unity. However, the Japanese spectra are significantly less effective, and the molybdenum mammography spectrum is significantly more effective than the mid-range energies. The estimated effectiveness (2.0) of molybdenum X rays relative to Hiroshima and Nagasaki γ rays is in good agreement with measured results (2.02) from Virsik et al (1981) at low doses for dicentric chromosomal aberration formation in human lymphocytes. In addition, the estimated effectiveness of the γ rays relative to 250 kVp X rays is consistent with the measured low-dose relative biological effectiveness (RBE) (1.9 ± 0.4 at 3 cGy) of orthovoltage X rays relative to ^{60}Co γ rays for *in vitro* oncogenic transformation (Borek et al, 1983).

The importance of understanding the effectiveness of the molybdenum mammography spectrum relative to the 80 kVp, 250 kVp and Japanese spectra is related to the benefit–risk comparisons necessary to assess the efficacy of mammographic screening. The factors that have to be balanced are the risks of developing breast cancer because of the radiation delivered during mammography against the benefits of early cancer detection. The risk estimates for breast cancer are primarily based on data from women exposed to 175–270 kVp X rays (Rochester mastitis patients), 70–85 kVp X rays (Massachusetts tuberculosis patients receiving fluoroscopic examinations) or γ rays (A-bomb survivors). On the basis of such data and studies on the benefits of screening (Shapiro et al, 1985; NCRP, 1986; Seidman et al, 1987; Feig, 1988), it is possible to estimate the relation between the benefit–risk ratio for mammographic screening and the age at screening. An increased hazard from molybdenum-based mammography would imply an increased age at which the benefit–risk ratio surpasses a certain desirable level.

The data in Fig. 4 can be used to exemplify this point. The data points are calculations (NCRP, 1986) made assuming that a yearly mammographic screening with medium-energy X rays (0.1 cGy/screening) results in a 20% benefit; these parameters are typical for molybdenum-based mammographic screening (NCRP, 1986). The risk estimates used to obtain the data points shown in Fig. 4 were derived from a joint analysis of Massachusetts women receiving ~80 kVp X rays and of Rochester women receiving ~250 kVp X rays. Thus from Table I, if molybdenum-based mammography is used, the curve describing the benefit–risk ratio should be moved down by a factor of 1.3 to account for the increased risk. If the much larger Japanese studies are used to derive low-dose risk estimates (Shimuzu et al, 1987; Tokunaga et al, 1987), then the benefit–risk curves for molybdenum-based X rays should be moved down by a factor of 2.0.

The effects of such shifts in the benefit–risk curves are

Table I. Estimated relative risks (at equal low doses) from the different photon spectra shown in Fig. 1

Molybdenum 23 kVp	Tungsten			Nagasaki	Hiroshima
	44 kVp	80 kVp	250 kVp		
1.29	1.02	1.00	0.98	0.67	0.62

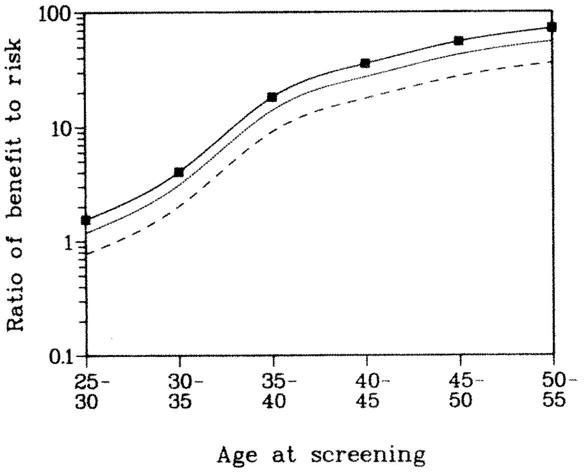

Figure 4. Ratio of benefit to risk for a mammographic screening at a given age. The calculations (from NCRP, 1986) are based on estimated breast cancer mortality, *i.e.* the number of lives saved/lost by a single screening at a given age (further details of the calculation may be found in Chiacchierini & Lundin, 1979). Points on the upper curve are derived from NCRP (1986) for a (typical) average glandular dose of 0.1 cGy and a (typical) screening benefit level of 20%, *assuming the screening X rays have unit RBE;* the full curve is a cubic-spline fit to these points. The two lower curves are, respectively, 1.3 times lower (dotted curve), and 2 times lower (dashed curve), corresponding to situations where the risk from mammographic screening is a factor of 1.3 or 2.0 times larger.

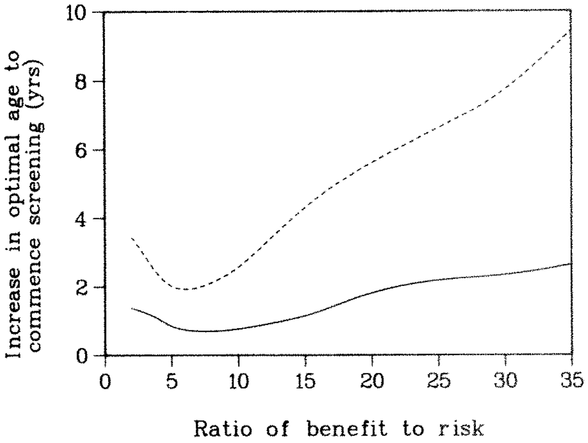

Figure 5. Increase in optimal age to begin screening (*i.e.* to attain the same ratio of benefit to risk) derived from the data in Fig. 4. The lower (solid line) curve is derived by assuming that the molybdenum-based mammography X rays have an increased risk of 1.3 compared with the X rays for which risk estimates are made (such as fluoroscopic examinations or mastitis therapy). The upper (dashed line) curve is derived by assuming that the mammography X rays have an increased risk of 2.0 compared with the γ rays at Hiroshima and Nagasaki, for which risk estimates may also be made.

shown in Fig. 5. The result will be an increase in the optimal age at which screening begins (*i.e.* the age at which the benefit–risk ratio reaches a given level). This increase depends on the minimum benefit–risk ratio considered acceptable, and also on the origin of the risk estimates. If the baseline risk estimates come from 70–270 kVp X rays, then the lower curve in Fig. 5 demonstrates an increase of between 1 and 3 years in the optimal age at which mammographic screening should begin. If the baseline risks are based on data from Hiroshima and Nagasaki, then the upper curve in Fig. 5 indicates a 2–10-year increase. If the baseline risk estimates are based on both the Japanese (high energy) and the American (medium energy) exposed groups, then the true optimal increase in the age to commence screening would lie between the two curves shown in Fig. 5.

The detailed results of this analysis depend on the form of the function $r(y)$ used to estimate the relative effectiveness factors shown in Table I. While the function that was used, $Q(y)$ from ICRU Report 40, is of necessity preliminary, it is unlikely that its basic shape will change. For example, a $Q(y)$ function derived for mutation induction in human fibroblasts (Zaider & Brenner, 1986) exhibits the same basic features. Thus the relative data in Table I are unlikely to change greatly.

The estimates of the shift in optimal age to begin screening with molybdenum-based X rays, in principle, depend also on the dose, the benefit of the screening and the ratio of benefit to risk considered acceptable. However, the shape of the benefit–risk against age curve does not vary greatly with dose or with benefit level (NCRP, 1986), and the estimates of the shift in optimal age shown in Fig. 5 are good to within a factor of 2. For example, if the estimates in Figs 4 and 5 were repeated assuming a benefit for mammographic screening of 40% (Feig, 1988) rather than 20%, the range of optimal increases estimated (for a 1.3 increased hazard) is from 0.8 to 1.5 years (as opposed to a range from 0.7 to 2.6 years shown in Fig. 5).

These results are, of course, for mammography performed with low-energy molybdenum X rays, but would be similar for other very low-energy machines used for screen–film mammography, such as one with a tungsten target operated at 23 kV without filtration (Stanton et al, 1987).

Acknowledgments

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Residual radiation-induced injury in dermal tissue: implications for retreatment

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Abstract. The evidence for residual radiation-induced injury has been investigated in the dermal vascular/connective tissue of pig skin at intervals of 17–52 weeks after irradiation. The primary irradiation was a single dose of 18 Gy, which represents the upper limit of "tolerance" to X irradiation of pig dermal tissue. Re-irradiation was with graded single doses of X rays in order to establish dose–effect relationships for the incidence of late ischaemic dermal necrosis of the skin; dose–effect curves obtained for previously irradiated skin were compared with those obtained using previously unirradiated skin in the same group of animals. At intervals of 17, 35 and 52 weeks after the primary treatment the resulting ED_{50} values for dermal necrosis were not significantly different from those obtained for previously unirradiated skin. This suggests little or no effective residual injury at these time intervals after a primary full "tolerance" dose. This conclusion was supported by the findings for the latency time for the development of dermal necrosis, which were similar in re-irradiated and previously unirradiated skin. Epithelial desquamation was not induced by the doses used in these studies, either after the primary treatment or after re-irradiation; however, the early erythema reactions seen in re-irradiated skin were markedly reduced, particularly when this was carried out after 35 and 52 weeks, when compared with skin that had not previously been irradiated. This suggests that the early erythema reaction may be a particularly poor predictor of late effects after the re-irradiation of the skin. Although the present results suggest that dermal and subcutaneous tissues may safely be retreated with a full tolerance dose at relatively early times after an initial radical treatment, caution is recommended in extrapolating these results to other late-responding normal tissues. In other tissues some persistent injury may be present even at very long time intervals after the primary treatment.

In radiotherapy, the problem of the retreatment of recurrent or residual malignant disease is complicated by the possibility of residual injury in normal tissues arising from the first radiation treatment. Publications based on clinical studies involving this topic are limited and are often conflicting. For example, in the retreatment of head and neck cancer by ^{60}Co γ rays the tolerance of the adjacent normal tissues to re-irradiation has been reported to be appreciably reduced (Skolyszewski et al, 1980). Similarly Langlois et al (1985) reported that while acute tolerance was close to normal, there were more frequent late complications after retreatment. On the other hand, re-irradiation of head and neck tumours with fast neutrons (Errington & Catterall, 1986) after previous photon irradiation was well tolerated by the adjacent normal tissues. When treating second malignancies in the hypopharynx, Hunter and Stewart (1977) also reported that there was no indication that the tolerance was at all reduced in heavily irradiated skin when compared with previously untreated normal skin. In addition, several other groups have published accounts of the successful re-irradiation of such tumours (Wang & Schulz, 1966; Chen & Fletcher, 1971). However, these clinical investigations were associated with many variables and it is not feasible to obtain precise quantitative information from them.

The increased long-term survival of patients following radical radiotherapy treatment has highlighted the need for more information concerning the tolerance of previously irradiated tissues, particularly late-responding normal tissues, to retreatment. This is particularly true for the vasculature, damage to which may well play an important role in the development of late radiation damage of the skin and other normal tissues (Hopewell, 1980; Hopewell et al, 1989). In view of the difficulties associated with the analysis of clinical results it seems likely that much of this data must be obtained from studies involving animal systems. Experimental studies on the tolerance of previously irradiated skin have been carried out on rodents; however, some of these studies (Brown & Probert, 1973) have involved the use of very high doses of radiation, which may have resulted in a high incidence of severe "late" effects such as limb loss and deformity as a consequence of the severe acute skin reactions (Hopewell, 1982, 1985a). Therefore, it is possible that results obtained using such systems are not relevant to the problem of the late radiation tolerance of the skin of patients.

Pig skin has been shown to be an excellent model for the study of the early and late effects of radiation on the skin owing to its markedly similar anatomy and response to irradiation when compared to human skin (Hopewell et al, 1978; Hopewell, 1985b; Hopewell & van den Aardweg, 1988). Therefore, it is likely that retreatment studies using pig skin will provide information that may be more directly applicable to the clinical situation.

Materials and methods

The flank skin of 11 female Large White pigs was used in these investigations. The animals were admitted to the animal house when approximately 12–14 weeks of age (20–25 kg) and were allowed an acclimatization period of 2 weeks before any experimental procedures were performed. Prior to irradiation three 16 cm × 4 cm fields, separated by 4 cm, were tattooed on the left flank; similar fields were also tattooed on the right flank. The fields on the left flank were each irradiated with a single dose of 18 Gy of X rays, using a 250 kV X-ray unit operating at 15 mA with 0.5 mm Cu and 1.0 mm Al added filtration (HVL 1.4 mm Cu). A Perspex-ended applicator (focus–skin distance 50 cm) in light contact with the skin, together with a 16 cm × 4 cm cutout in 4 mm lead, were used to delineate the irradiated fields. The dose-rate was 0.64–0.68 Gy min − 1. The exit dose to the contralateral flank skin was <8%. All procedures were carried out with the pigs anaesthetized with a mixture of 2% halothane, ~30% nitrous oxide and ~70% oxygen.

At intervals of 17, 35 and 52 weeks after the initial radiation exposure, three 4 cm × 4 cm fields, separated by 4 cm, were tattooed within each of the original treatment fields on the left flank. These fields were re-irradiated with a range of single doses of X rays. After an interval of 17 weeks the re-irradiation doses were 15.3, 18.0, 20.7 and 23.4 Gy, at 35 weeks 17.3, 20.0 and 22.7 Gy, and at 52 weeks 16.2, 18.6, 21.06 and 23.8 Gy. Between four and 13 fields were irradiated at each dose level. Single doses of 18.0, 20.7 and 23.4 Gy were given to 4 cm × 4 cm fields on equivalent sites on the right flanks of the same group of pigs. These served as "irradiation controls" (Fig. 1). Owing to the increase in the size of the animals, the exit doses in each instance were negligible.

During the first 16 weeks after re-irradiation or irradiation of the "control" fields, the skin reactions of all fields were assessed using a scoring system which recorded the degree of erythema and the occurrence and extent of moist desquamation or dermal necrosis (Hopewell et al, 1978). Assessments were made at weekly intervals by at least four observers. Since the time course of the skin reaction after single doses of X rays was known to be biphasic (Peel et al, 1984), mean erythema scores were calculated over the two waves of radiation response, *i.e.* 3–9 weeks for the initial, epithelial wave of response and 10–16 weeks for the second, dermal wave of response. Moreover, for each dose, the proportion of fields that progressed to dermal necrosis over the course of the second wave reaction was recorded. The ED_{50} ($\pm$SE) values were obtained from dose–effect curves showing the incidence of dermal necrosis, which were fitted by probit analysis.

The mean latency time for the development of necrosis was also assessed for "control" and re-irradiation skin fields at dose levels that gave rise to a $\geq 50\%$ incidence of dermal necrosis.

Results

The dose-related changes in the average erythema scores from 3 to 9 weeks, for each of the three re-irradiation intervals and their corresponding "irradiation controls" in previously unirradiated areas of skin, are shown in Fig. 2. Since the data for the "irradiation control" areas were similar for each treatment interval, the results have been combined, and a linear regression fit to these combined data is plotted. There was a dose-dependent increase in the average erythema scores for all the re-irradiation times. A similar but less pronounced dose-dependency was noted in the "irradiation control" fields. The average erythema scores obtained after re-irradiation, following an initial dose of 18 Gy, were considerably lower than the "irradiation control" values. Re-irradiation after 17 weeks with a dose of 18 Gy resulted in an average erythema score of 1.13 ± 0.15 compared with a score of 1.5 ± 0.05 for fields receiving 18.0 Gy alone. This difference was significant ($p < 0.025$). On the other hand, re-irradiation with a dose of 23.4 Gy resulted in an average erythema score similar to that observed in "irradiation control" fields receiving the same dose ($p > 0.05$). The suggestion of a reduction in the average

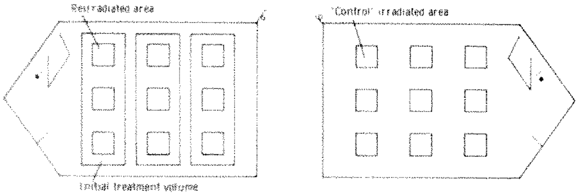

Figure 1. Diagrammatic representation of the irradiation fields on the flanks of pigs. Three fields on the left flank received the initial single doses of 18.0 Gy. Within each of these fields three 4 cm × 4 cm areas subsequently received a range of re-irradiation doses after 17, 35 or 52 weeks. Nine 4 cm × 4 cm fields were included on the right flanks, which received single doses of 18.0, 20.7 or 23.4 Gy concurrently with the re-irradiation doses to the left flank.

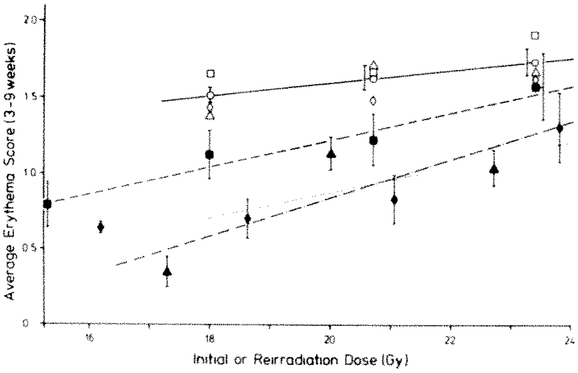

Figure 2. Dose-related variations in the average erythema score ($\pm$SE) 3–9 weeks after irradiation. Re-irradiation doses were given at 17 (■), 35 (▲) and 52 (◆) weeks after a single dose of 18 Gy. Comparable data for the combined "irradiation control" series are given. The individual mean "control" values at each retreatment interval are represented by the appropriate open symbols.

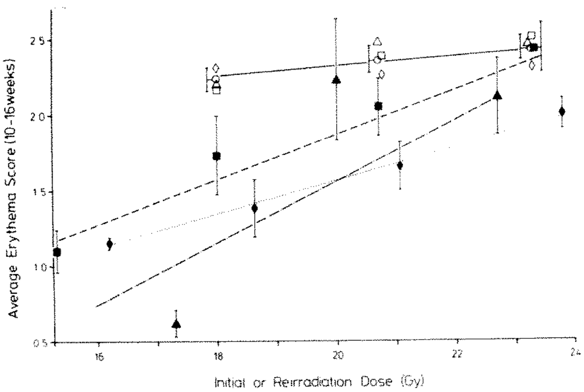

Figure 3. Dose-related variations in the average erythema score (±SE) 10–16 weeks after irradiation. Symbols as in Fig. 2.

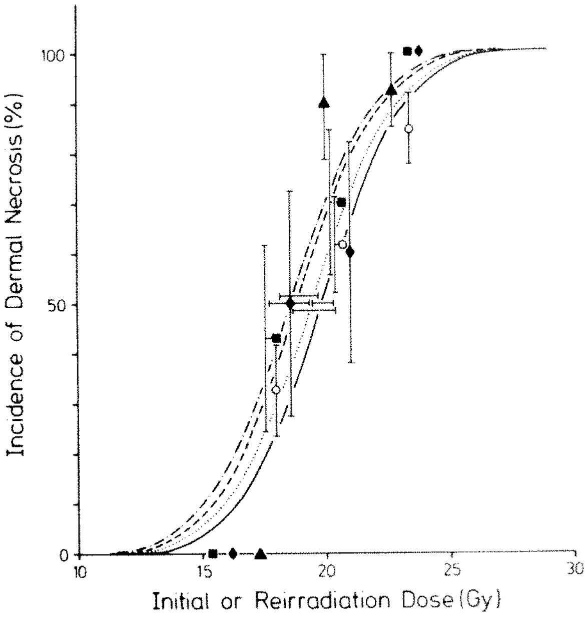

Figure 4. Dose-related changes in the percentage of skin fields developing dermal necrosis after irradiation or retreatment: ■, re-irradiation after 17 weeks; ▲, re-irradiation after 35 weeks; ◆, re-irradiation after 52 weeks; ○, "irradiation control" doses. Errors indicate mean ± SE.

erythema score following re-irradiation after 17 weeks was even more pronounced in fields re-irradiated at 35 and 52 weeks for skin fields receiving similar doses (Fig. 2).

The dose-related changes in the average erythema scores obtained for the second wave of the radiation response, *i.e.* the dermal response occurring between 10 and 16 weeks after irradiation, are shown in Fig. 3. The patterns of response obtained were similar to those described for the earlier epithelial response. However, the average erythema scores obtained for the re-irradiated fields were markedly lower than those observed for the "irradiation control" skin fields, particularly in those fields re-irradiated at 35 and 52 weeks after the initial dose of 18 Gy. These results indicated that, on the basis of erythema scores, re-irradiation of skin fields that had initially received a single dose of 18 Gy led to a reduction in the degree of erythema compared with skin fields that had received no previous irradiation.

The dose–effect curves for the incidence of dermal necrosis following re-irradiation at 17, 35 and 52 weeks after a single dose of 18 Gy are shown in Fig. 4. The curve for the combined "irradiation control" data is also given for comparison. From these curves the doses required to produce a 50% incidence of dermal necrosis ($ED_{50} \pm SE$) were obtained. For the combined "irradiation control" skin fields this was 19.83 ± 0.45 Gy. This value was not significantly different from the ED_{50} values for skin fields re-irradiated at 17, 35 and 52 weeks after an initial dose of 18.0 Gy, *i.e.* 18.93 ± 0.76, 18.56 ± 0.84 and 19.48 ± 0.92 Gy, respectively. The estimates of the percentage of residual injury remaining from the initial dose indicated that there was little change in the percentage dose recovered with increasing the retreatment interval (Table I). Thus, at 17 weeks after an initial single dose of 18.0 Gy, pig skin exhibited only 5.00 ± 4.91% residual injury, at 35 weeks after irradiation this residual injury was 7.06 ± 5.29% and by 52 weeks the percentage of residual injury remaining was 1.94 ± 5.69%. These values, expressing the proportion of residual injury, were not significantly different from zero ($p > 0.2$).

The latency times for the appearance of dermal necrosis after re-irradiation with the two highest doses, for each re-irradiation time and for the "irradiation control" fields, are shown in Table II. For each retreatment group there was a tendency for the mean latency time to be shorter after the higher dose. However, in none of these groups did the differences prove to be statistically significant ($p > 0.2$). A similar relationship was seen for the "irradiation control"

Table I. ED_{50} values (±SE) for dermal necrosis in pig skin re-irradiated at 17, 35 or 52 weeks after an initial dose of 18 Gy. The ED_{50} value for previously unirradiated skin is quoted along with the estimates of the proportion of residual injury (±SE)

Retreatment interval (weeks)	$ED_{50(Gy)}$	Residual injury[a] (%)
17	18.93 ± 0.76	5.00 ± 4.91
35	18.56 ± 0.84	7.06 ± 5.29
52	19.48 ± 0.92	1.94 ± 5.69
"Irradiation control"	19.83 ± 0.45	(1.00 ± 0.02)

[a] $\text{Residual injury} = \dfrac{ED_{50(\text{control})} - ED_{50(\text{retreatment})}}{18\,\text{Gy (initial dose)}}$

Table II. Latency (±SE) for the development of dermal necrosis in pig skin after various retreatment doses

Retreatment interval (weeks)	Dose (Gy)	Latency (weeks)	Dose (Gy)	Latency (weeks)	p
17	20.7	11.3±1.3	23.4	10.0±0.3	> 0.3
35	20.0	11.3±0.4	22.7	11.0±0.6	> 0.5
52	21.1	12.7±0.9	23.8	10.9±1.3	> 0.2
"Irradiation control"	20.7	12.9±0.7	23.4	10.3±0.6	< 0.005

fields, but on this occasion the difference was significant ($p < 0.005$). When retreatment and "irradiation control" fields were compared after similar doses there was no significant difference between the latencies for necrosis ($p > 0.2$).

Discussion

For acute radiation reactions of the skin of the mouse foot, earlier studies have shown that there was little or no evidence of residual injury when a second course of irradiation was given from 12 weeks or later after the primary treatment (Brown & Probert, 1975; Denekamp, 1975; Hendry et al, 1977). In these studies relatively large primary treatments were sometimes used, which could in themselves produce either a transient desquamation or a more severe moist desquamation, with a resultant persistent tissue lesion (Hopewell, 1982, 1984). The re-irradiation doses used for the assay of residual injury also resulted in the development of moist desquamation, the arbitrary scoring systems used for assessing radiation-induced damage being largely related to the evaluation of varying degrees of severity of moist desquamation. In the present investigations in pig skin, doses below the threshold for the development of moist desquamation were used both for the primary dose and for the various re-irradiation doses; only an erythematous reaction was seen. For this level of response, average reaction scores between 3 and 9 weeks after re-irradiation were significantly less, at all three time periods at which residual injury was assessed, than those for comparable areas of skin that had not received previous irradiation. A similar phenomenon has been reported for mouse skin retreated 6 months after a primary dose of 15 Gy (Terry et al, 1989). This effect was particularly noticeable after irradiation doses of ⩽ 25 Gy, when erythema was the predominant reaction seen.

One possible explanation of the finding in pig skin is that it represents a truly reduced radiosensitivity of irradiated skin, caused by hypoxia induced as a consequence of vascular injury resulting from the initial irradiation dose. A single dose of 18 Gy is known to produce a transient reduction in dermal blood flow, which was particularly marked at 12 weeks after irradiation (Moustafa & Hopewell, 1979). Evidence for hypoxia was also provided by the clinical appearance of the skin at 10–16 weeks after radiation when the erythematous reaction had a distinct dusky-mauve appearance (Hopewell et al, 1979; Hopewell, 1980; Hopewell & Young, 1982). Split-dose studies involving the acute radiation reaction of pig skin, with an interfraction interval of 9 weeks, have also provided evidence for radiation-induced hypoxia (van den Aardweg et al, 1988). However, experiments in rodent skin with misonidazole indicated that the oxygenation status of previously irradiated skin was not significantly changed after an interval of 90 days (Wondergem & Haveman, 1987).

An increase in the proportion of hypoxic cells was also proposed as one possible explanation for the relative radioresistance of re-irradiated skin compared with previously untreated skin in the legs of mice (Masuda et al, 1986). Re-irradiation was from 6 weeks to 12 months after the primary treatment. Although hypoxia might possibly explain these results in rodent skin, it is unlikely to provide an adequate explanation of the results obtained in pig skin when re-irradiation was carried out after intervals of 35 and 52 weeks, when the reduction in the severity of erythema was even more marked. At these later times after irradiation, when the dermis was atrophic (Hopewell, 1980; Baker et al, 1989), the resting regional blood flow was comparable to that in unirradiated skin (Moustafa & Hopewell, 1979) and hence induced hypoxia is unlikely.

An alternative explanation for the reduction in the severity of the erythema reaction in re-irradiated skin at these later times, and possibly at the earlier time, may be a change in the reactivity of irradiated blood vessels to an inflammatory stimulus. When split-thickness grafts were removed from areas of irradiated skin a modification in the bleeding pattern from the cut surface was noted (Young & Hopewell, 1986). A dose-dependent increase in bleeding occurred, irrespective of whether the grafts were cut at 3, 12 or 32 weeks after irradiation. This increase was attributed to the inability of irradiated vessels to constrict after trauma; a physiological change, since no major structural modifications were seen in the walls of vessels at 3 weeks after irradiation. Surgical studies have also provided evidence for a reduction of the ability of irradiated vessels to dilate after trauma. At 6–24 months after irradiation with a single dose of 18 Gy, the surviving length of pedicle skin flaps was reduced even though the resting blood flow in irradiated skin was not significantly different from that in unirradiated skin (Hopewell, 1980). The early erythematous reaction of the skin, 3–9 weeks after irradiation, has been reported to represent a secondary inflammatory reaction of the vasculature to epithelial cell damage (Hopewell, 1983). A reduction in the vasoactive response in previously irradiated skin for a similar level of epithelial cell damage would explain the present findings in pig skin.

A major objective of the present investigations was to establish evidence for residual irradiation damage in the later-responding dermal vascular/connective tissues of the pig. Based on the assay of the incidence of ischaemic dermal necrosis there would appear to be no evidence for any significant residual dermal injury when re-irradiation was carried out at 17, 35 or 52 weeks after a primary dose of 18 Gy. This single dose of 250 kV X rays is close to the threshold for the development of dermal necrosis in pig skin—"tolerance". Previous studies have demonstrated a low incidence of necrosis in 16 cm × 4 cm skin fields after this dose (Hopewell & Young, 1982). Moreover, in this study none of the fields receiving the primary treatment developed necrosis. The incidence of necrosis in the 4 cm × 4 cm "control" irradiation fields was higher than that based on previous experience (Hopewell & Young, 1982), but not significantly so.

Further evidence that there was little or no residual injury at these late times was obtained from the data for the latency of the development of necrosis after re-irradiation; this showed no difference in latency between re-irradiated and "control" irradiated areas for comparable dose. Based on the model proposed to explain the effects of re-irradiation of the spinal cord (van der Kogel, 1986), this would imply that the functional cell or subunit number had returned to normal, with no permanent residual injury to the dermis.

Whether this implies repopulation of the relevant target cell population for this late reaction is uncertain. In a comparison of the time of onset and rate of recovery based on dose escalation in split-dose studies (van den Aardweg et al, 1988), "acute" and "late"-responding tissues showed a similar pattern of response, albeit that the time of onset of additional recovery was considerably delayed in late-responding tissues.

In pig skin there was an initial reduction in the vascular density after irradiation; this approached a maximum at around 12 weeks (Hopewell, 1983). At later times the vascular density and the resting blood flow per unit volume of tissue were apparently normal (Moustafa & Hopewell, 1979). However, this does not represent a restoration of the capillary network but reflects a loss or atrophy of the parenchymal tissues. A single dose of 18 Gy results in a 10% reduction in the linear dimensions of an irradiated area 26–52 weeks (Hopewell et al, 1979). Parenchymal atrophy in dermal tissue is associated with a greater loss of fibroblast nuclei, relative to collagenous material, with a permanent deficit in this cell type at late times after irradiation (Hamlet & Hopwell, 1988). The apparent absence of any significant degree of residual injury persisting after this dose, as indicated by the results of these investigations, would suggest, extrapolating from the model proposed by van der Kogel (1986), that fibroblasts are not the target cell type involved in the development of late radiation-induced injury.

The present findings in pig dermal tissue would not appear to be in agreement with those of Brown and Probert (1975), who found a significant memory of previous irradiation when damage characterized as foot "deformity" in the mouse was used for the assay. In this instance the percentage residual injury depended on the size of the primary treatment, amounting to 17–26% and ⩾ 32% after 10 × 3 Gy and 10 × 5 Gy, respectively. These doses in themselves produced a severe early moist desquamation that might persist for a considerable period of time in some mice. This in itself might cause some scarring of the deeper dermal tissues, albeit as suggested by the original authors occurring at a subclinical level. There has been considerable debate about the use of the "deformity" endpoint in radiobiological studies (Denekamp, 1977) and its clinical relevance as an assay of late radiation-induced injury has been called into question (Hopewell, 1982, 1985a), the general consensus being that the deformity scale, as first described by Field (1969), is really the result of severe and persistent acute lesions and not a true late effect. In the case of the re-irradiation studies by Brown and Probert (1975), the increase in the severity of deformity after the second course of irradiation might simply represent the addition of two subclinical levels of injury to deeper tissues resulting from the severe acute reactions. The appearance of the lesion in the studies by Brown and Probert (1975) also appeared to be different from the classic deformity reaction (as reported by Hopewell, 1982).

The results of the studies in pig skin would, however, appear to be in agreement with those for human skin. After a latent interval of ⩾ 15 years, even patients with marked late skin changes from the primary therapy showed a late skin tolerance comparable to that of normal previously unirradiated skin (Hunter & Stewart, 1977). Radical radiotherapy of head and neck cancers with fast neutrons 1–24 months after previous radiotherapy and surgery was also well tolerated by the skin, with no greater than expected late reactions (Errington & Catterall, 1986). On the other hand, Langlois et al (1985) reported an increase in complications after the re-irradiation of head and neck cancers with photons. However, it should be noted that most of these complications were related to tumour lysis and that no significant cutaneous reactions were observed.

The latter result raises the question of the type of adverse reaction reported after re-irradiation and the inherent dangers of extrapolating results obtained from one tissue, in this instance the dermis, to other late-responding tissues. In organs such as the kidney and spinal cord there is evidence from simple split-dose studies (van den Aardweg et al, 1988) that although some recovery is possible, it is incomplete, and that some level of permanent but subclinical injury persists. The presence of subclinical injury may go undetected in organs such as the kidney when damage is assessed on the basis of the impairment of function because of the existence of an extensive physiological reserve in these tissues. This may explain the presence of residual injury in the mouse kidney at 6 months, even after an initial dose as low as 6 Gy (Stewart et al, 1988). The concept of permanent residual injury was included in a model to explain the development of white-matter necrosis in the rat spinal cord as derived from the results of split-dose experiments (van der Kogel, 1986). Such a hypothesis has recently been supported by the results of histological investigation in the irradiated rat brain, where a "unit of tissue injury" was identified that precedes the development of white-matter necrosis at higher doses but persists as a subclinical lesion at doses just below the threshold for necrosis (Calvo et al, 1988). The results of re-irradiation studies in other late-responding organ systems, involving various primary irradiation doses that may or may not result in subclinical injury, are now awaited before a more rational approach to re-irradiation can be established.

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Radiation doses in extracorporeal shock wave lithotripsy

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Abstract. Patients undergoing lithotripsy on the Siemens Lithostar system are exposed to radiation in three modes: film radiography, electronic radiography and fluoroscopy. Radiation exposure techniques (kVp, field size, number of exposures and projection) were recorded for the first 125 patients undergoing treatment on a recently installed Lithostar unit at a Winnipeg hospital. These data were then used in conjunction with phantom-based radiation dose measurements to calculate entrance skin dose and total energy imparted for each patient. Values of 142 mGy and 53 mJ, respectively, were found. In the case of energy imparted, 20% of the total arose from film radiography, 30% from electronic radiography and the remaining 50% from fluoroscopy. The estimated effective dose-equivalent, H_E, to the average patient undergoing lithotripsy was 0.75 mSv. This corresponds to an estimated radiation risk for the induction of fatal cancers and genetic defects (in the first two generations of offspring) of between 5 and 11 per million.

Extracorporeal shock wave lithotripsy (ESWL) is rapidly becoming the preferred treatment modality for renal and upper ureteral calculi. This treatment modality uses ionizing radiation both to localize the calculi and to establish their successful fragmentation. Although some work has been reported on the radiation doses to patients treated on the Dornier water bath system, few data are available for the more recent Siemens Lithostar lithotripter (Bush et al, 1987; Lin & Hrejsa, 1987; van Swearingen et al, 1987). Furthermore, most work to date has reported radiation doses in terms of total entrance exposures at the patient surface. Although this radiation dose parameter is readily measured, it is a poor indicator of patient risk when there are significant variations in technique (*i.e.* X-ray beam field size) during the different radiographic/fluoroscopic components of the imaging process. Under these circumstances, radiation risk is more appropriately described by the total energy imparted to the patient, E (Bengtsson et al, 1978; Shrimpton et al, 1986) or by the effective dose-equivalent parameter, H_E [United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 1982; Huda & Sandison, 1986]. The use of E and/or H_E to describe dose not only enables patient radiation risks to be quantified but also makes possible a comparison with the corresponding risks associated with other diagnostic procedures such as conventional radiology, computed tomography and nuclear medicine.

In this paper, radiation doses are reported for the first 125 patients undergoing ESWL on a recently installed Siemens Lithostar unit at the Health Sciences Center (HSC) in Winnipeg, Manitoba. Doses are expressed in terms of both total entrance dose and total energy imparted. Special attention is paid to the relative importance of the three imaging modes available on the Lithostar: film radiography, electronic (or digital) radiography (ER) and fluoroscopy. An estimate of the average effective dose-equivalent to an ESWL patient is also made and the resultant radiation risk evaluated.

Method

Lithostar energy imparted estimates

Imaging tasks carried out during treatment with a Lithostar unit may be performed in one of three modes: film radiography, electronic radiography or fluoroscopy. The Lithostar uses a double X-ray tube/image-intensifier system to enable the acquisition of two different projections, an antero-posterior (AP) and an oblique (38° to the vertical). In the fluoroscopic and electronic radiography modes of operation, images may be acquired in either plane. Film radiography, on the other hand, is restricted to AP projections.

A complete record was compiled of the exposure techniques used in the treatment of the first 125 patients undergoing lithotripsy on the Lithostar unit. The data recorded included kVp, field size, number of exposures (or fluoroscopy time), projection and mAs setting for ER.

The energy imparted by each of the three radiographic procedures used in lithotripsy treatment was calculated using the expression.

$$E = D_0 \, A_0 \, p \, EF \qquad (1)$$

where D_0 and A_0 are the absorbed dose and beam area at the surface of the patient, respectively, p is the density of tissue (assumed to be water equivalent), and EF is referred to as the energy factor of the exposure and represents the summation of terms in the energy imparted expression of Harrison (1983).

Calculation of the EF associated with a particular X-ray procedure requires knowledge of the source-to-surface distance (SSD), patient thickness and the shape of the absorbed dose against depth curve characteristic of that technique. The shape of the dose against depth curve will be dependent on the peak tube potential (kVp), beam half-value layer (HVL) and entrance surface field size. Energy factors associated with radiographic procedures using five different beam qualities (*i.e.* kVp and HVL) and six different field sizes were calculated using published experimental depth–dose data (Harrison, 1981). An SSD of 60 cm and a patient thickness of 20 cm were assumed to be typical of lithotripsy radiographic procedures and used in all calculations. The *EF* associated with an arbitrary radiographic procedure was estimated through interpolation of these results.

Electronic radiography and fluoroscopic procedures can be carried out using one of three pre-set field sizes, referred to as small, medium and large. Film radiographs, on the other hand, can be taken with only two field sizes, small and large. The areas covered by these fields at the patient entrance surface were determined by positioning a 20 cm thick wood block on the lithotripsy patient table and measuring the lengths and widths of the associated light fields. The results are presented in Table I.

Estimates of the entrance surface exposure characteristic of each of the three radiographic techniques were obtained experimentally from phantom measurements. A 20 cm thick block phantom (composed of a tissue-equivalent material) was placed on the lithotripsy table to simulate a typical patient. An ion chamber (MDH meter 1015, Radcal Corporation) fastened to the entrance surface of the phantom served to measure exposure (or exposure rate in the case of fluoroscopy) at the field centre. Readings were taken in all three imaging modes. In the case of fluoroscopy, exposure rate measurements were made at five kVp settings, three field sizes and for both the AP and oblique views. Exposure rates were then converted to absorbed dose-rates in muscle using a multiplication factor of 0.925 (Wall et al, 1988). Cubic spline interpolation was used to estimate the exposure rate associated with any arbitrary tube peak potential between 60 and 100 kVp. Similar measurements were performed for both electronic radiography (at 100 mAs) and film radiography. In the case of the latter, films were exposed using automatic exposure control (AEC), a technique used in clinical applications whereby either one or two chambers automatically terminate the exposures.

A computer program incorporating the interpolated *EF*s and entrance exposures, as well as the measured field sizes discussed previously, was used to calculate the energy imparted to patients undergoing fluoroscopy, electronic radiography and film procedures as part of their lithotripsy treatment. As input variables, the program required the type of procedure (fluoroscopy, electronic radiography or film radiography), the projection used (AP or oblique), field size (small, medium or large), peak tube potential and the number of exposures acquired (or the time of exposure in the case of fluoroscopy).

Table I. X-ray beam areas at patient entrance, where the patient thickness is taken to be 20 cm and the source-to-skin distance 60 cm

Operating mode	Field size (cm^2)	
	AP	Oblique
Film radiography		
Large	828	—
Small	408	—
Electronic radiography		
Large	121	136
Medium	72	66
Small	34	29
Fluoroscopy		
Large	121	136
Medium	72	66
Small	34	29

Lithostar radiation risks

The radiation risks to an individual exposed at the levels normally encountered in diagnostic radiology are generally considered to be the induction of fatal cancers and serious genetic effects in the irradiated individual's offspring (first two generations). At present, the risk is estimated at 1.65×10^{-2} Sv^{-1} with approximately 75% of this value being attributed to the risk of induction of fatal cancers [International Commission on Radiological Protection (ICRP), 1977a]. It is important to note that there are considerable uncertainties associated with

Table II. Effective dose-equivalent conversion factors

Type of irradiation	Conversion factor	Reference
Uniform whole body	14.3 $\mu Sv\ mJ^{-1}$	ICRP, 1975 ICRP, 1977a
CT, head	10.5 $\mu Sv\ mJ^{-1}$	Huda, 1984 Huda & Sandison, 1986
CT, chest	28.1 $\mu Sv\ mJ^{-1}$	Huda, 1984 Huda & Sandison, 1986
CT, abdominal	14.2 $\mu Sv\ mJ^{-1}$	Huda, 1984 Huda & Sandison, 1986
CT, pelvic	17.8 $\mu Sv\ mJ^{-1}$	Huda, 1984 Huda & Sandison, 1986
PA chest radiography (between 80 and 135 kVp)	17.7 $\mu Sv\ mJ^{-1}$	Huda et al, 1989a

Table III. Exposure techniques used on the first 125 patients undergoing ESWL at the Health Sciences Center in Winnipeg, with the entrance doses and energies imparted per exposure to patients of 20 cm thickness. The average number of films per patient was 1.6, the average number of electronic radiographs was 9.9 and the average fluoroscopy time per patient was 3.1 min

Operating mode (values in parentheses are % of field size use in each mode)	kVp	Entrance dose (mGy in muscle)		Energy imparted (mJ)	
		AP	Oblique	AP	Oblique
Film radiography					
Large field (10.7)	80 ± 8	2.1	—	11.8	—
Small field (89.3)	84 ± 9	2.1	—	5.7	—
Electronic radiography[a]					
Large field (26.4)	80 ± 12	3.9	6.2	2.8	5.0
Medium field (15.1)	81 ± 11	3.7	5.1	1.5	1.9
Small field (58.5)	84 ± 12	3.9	5.3	0.6	0.7
Fluoroscopy[b]					
Large field (20.1)	84 ± 16	26.8	36.6	19.1	29.8
Medium field (15.1)	91 ± 16	27.0	37.6	10.9	13.8
Small field (64.8)	88 ± 9	24.4	33.1	3.9	4.4

[a] Performed at average patient mAs of 105.
[b] For fluoroscopy time of 1 min.

the risks of low-level exposures [National Academy of Sciences (NAS), 1980]. In fact, these radiation risks are presently under review and seem likely to undergo an upward revision in the near future (Fry & Sinclair, 1987; Rotblat, 1988).

Two different approaches may be used to obtain a radiation risk estimate for lithotripsy treatment. First, the average energy imparted (X ray) to a patient can be directly converted into an estimate of risk using a "multiplication factor" of 2×10^{-7} cases per mJ of energy imparted (Bengtsson et al, 1978). An alternative approach is to convert the energy imparted into an effective dose-equivalent, H_E, a parameter first introduced in 1977 by the ICRP to account for non-uniform irradiation (ICRP, 1977a). This H_E can then be used in conjunction with the risk per Sv value of 1.65×10^{-2} Sv^{-1} to calculate a suitable risk for lithotripsy procedures. An examination of the conversion factors for energy imparted to effective dose-equivalent shows a remarkably narrow range of values (see Table II). A value of 14.2 $\mu\mathrm{Sv}\ \mathrm{mJ}^{-1}$ (*i.e.* abdominal) was assumed to be a suitable estimate of the conversion factor for lithotripsy.

Results

Lithostar energy imparted estimates

Data collected on the exposure techniques for each of the 125 patients included in this study were used to find mean kVp, mean number of exposures (or total exposure time) and the relative frequency of field size for each of the three imaging modes. These results are summarized in Table III, together with values of the entrance skin doses and corresponding energy imparted values associated with each of the three X-ray modes. These data correspond to a 20 cm thick patient undergoing a single film or ER exposure (or dose-rate in the case of fluoroscopy) and clearly demonstrate the importance of entrance field size on the energy imparted

Table IV. Distribution of energy imparted to patients during fluoroscopy, electronic radiography and film radiography

Energy range (mJ)	Number of patients			
	Fluoroscopy	Electronic radiography	Film radiography	Total
0.0– 9.9	25	74	74	2
10.0–19.9	34	25	36	9
20.0–29.9	28	10	13	24
30.0–39.9	16	2	2	24
40.0–49.9	8	5	0	29
50.0–59.9	4	4	0	9
>60.0	10	5	0	28
Mean energy imparted (mJ)	26.6	15.9	10.4	53.0
Standard deviation (mJ)	23.1	30.0	7.5	42.9

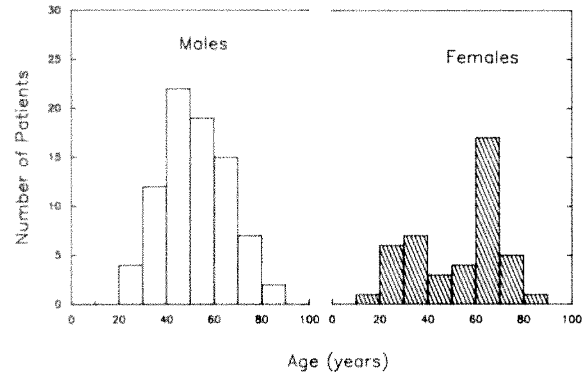

Figure 1. Age distribution of patients undergoing ESWL at the Health Sciences Center in Winnipeg. Total number of patients was 125, with males accounting for 65% of the total.

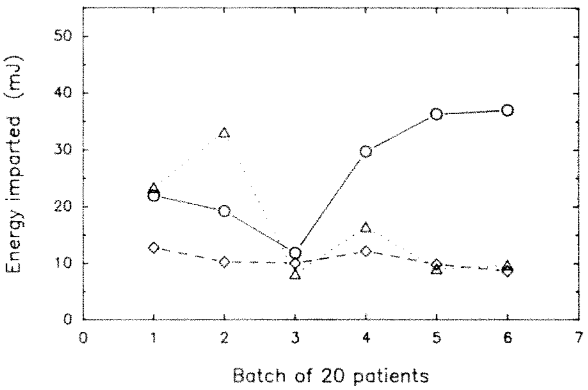

Figure 2. Average energy imparted by each radiographic mode (△, electronic radiography; ○, fluoroscopy; ◇, film radiography) for sequential batches of 20 patients.

parameter. The entrance skin dose associated with an average lithotripsy procedure as described by the data in Table III is 142 mGy.

Energy imparted values calculated on an individual basis for each of the 125 patients of this study are presented in summary form in Table IV. The mean energy imparted for fluoroscopy, ER and film radiography was found to be 26.6, 15.9 and 10.4 mJ, respectively. The mean total energy imparted was 53.0 mJ. It is important to note that the standard deviations associated with these averages are quite large, implying that many patients will receive "doses" that are markedly different from the mean. For example, the largest estimate of E for a single patient (total of all three X-ray modes) was 326 mJ, a factor of six higher than the average.

Lithostar radiation risks

Figure 1 shows the age distributions of the 125 patients included in this study, in which 65% of the patients were males, with a mean age of 52.1 ± 13.4 years, while the remaining 35% females had a mean age of 52.8 ± 17.9 years. The age distribution of a patient population is important because it has an effect on the probability that radiation-induced detriment (*i.e.* carcinogenesis and genetic effects) will be expressed. Using data presented in ICRP Report 27 (1977b), it is possible to show that for the Winnipeg "lithotripsy population", the probability of radiation-induced cancers being expressed is 0.47 for males and 0.49 for females. The corresponding probabilities of radiation-induced disorders being expressed in the offspring of this population is 0.07 for males and 0.11 for females. These data will be incorporated into the calculation of radiation risk from effective dose-equivalent.

The average energy imparted (X ray) to a patient undergoing a lithotripsy procedure on the Lithostar was found to be 53 mJ. This value can be directly converted into an estimate of the risk of late injury using the multiplication factor of 2×10^{-7} cases per mJ as described previously. A risk of 11 per 10^6 is obtained. Conversely, the average energy imparted associated with lithotripsy can be converted to an effective dose-equivalent of 0.75 mSv. This corresponds to a risk of 5 per 10^6 when account is taken of the age distribution of the patient population. Thus the radiation risk in a Lithostar lithotripsy procedure appears to be very low, falling within the range 5–11 per 10^6. Once again, it should be emphasized that there are considerable uncertainties associated with the risks of low-level exposures and in all likelihood the risk factors used in this report will undergo an upward revision in the near future.

Discussion

Traditionally, radiation dosimetry in diagnostic radiology has used entrance skin doses to characterize patient dose. Unfortunately, this approach suffers from two major drawbacks. First, because entrance skin dose ignores factors such as X-ray field size, it is not directly related to patient risk. Secondly, the fields used in different projections may not overlap, giving rise to the problem of additivity of disparate (*i.e.* non-overlapping) entrance skin doses. This is particularly true with the Dornier-type lithotripter, where the X-ray fields for the two projections are on different sides of the patient's abdomen. Nonetheless, it is common practice to state entrance skin dose as the simple sum of the non-overlapping skin doses of the two projections (Lin & Hrejsa, 1987; van Swearingen et al, 1987).

In this study, the first problem is overcome by arriving at radiation risks using the more appropriate parameters of energy imparted, E, and effective dose-equivalent, H_E. The second drawback is not encountered with the Siemens Lithostar unit since there is always an overlap of the film radiography and fluoroscopy/ER fields. Partial overlap between the AP and oblique fields is also present at all three field sizes. As such, it is appropriate to sum the entrance skin doses.

Although there are clear limitations to the usefulness of entrance skin dose measurements, it is of interest to compare the more recent Lithostar systems with the

Dornier units in this respect. The cumulative skin dose for Dornier systems is generally in the range 150–260 mGy (Bush et al, 1987; Lin & Hrejsa, 1987; van Swearingen et al, 1987). The Dornier system operates in two radiographic modes, electronic radiography and fluoroscopy, the latter accounting for 81% of the cumulative entrance dose in one study (Lin & Hrejsa, 1988), 56% in another (van Swearingen et al, 1987). These results show that the Lithostar system subjects patients to lower cumulative entrance skin doses. In addition, it should be noted that patients undergoing Dornier lithotripsy may also have diagnostic quality radiographs performed on conventional radiographic equipment. This would correspond to the film radiographs taken on the Lithostar, which contributes 20% to the total energy imparted estimates associated with the Siemens unit.

The average total entrance skin dose to a patient undergoing an ESWL procedure (Table III) was 142 mGy with 65% of this value being due to fluoroscopy, 33% to ER and the remaining 2% to film radiography. The average total energy imparted was found to be 53 mJ, with 50% of this value being due to fluoroscopy, 30% to ER and 20% to film radiography. In this example, the relative importance of film radiography increases by an order of magnitude when moving from entrance dose to energy imparted and clearly underlines the superiority of the latter parameter for radiation risk assessment.

As lithotripter operators gain more experience with this new treatment modality, patient exposure may be expected to decrease. Figure 2 shows the temporal variation in mean energy imparted for the three radiographic modes. Each point plotted represents the mean of data collected for groups of 20 patients. The total time required to treat the 120 patients incorporated in this figure was 14 weeks. Overall, the average total energy imparted has been relatively constant, although there are very large variations between individual patients. The same may be said of film radiography exposures. The use of ER has undergone a substantial decrease and fluoroscopy a significant increase. Reports in the literature on earlier lithotripter units have shown reductions in the entrance skin dose of the order of 35% over a period of 3 months (van Swearingen et al, 1987).

The average energy imparted to a patient undergoing a lithotripsy procedure on the Winnipeg Lithostar is approximately 53 mJ. This value can be directly compared with other diagnostic examinations performed in England in 1983 and reported recently by Shrimpton et al (1986). Lithotripsy falls between the "low-dose" studies such as chest (4.4 mJ) and skull (21 mJ) examinations and the "high-dose" studies such as intravenous urography (281 mJ), barium meals (231 mJ) and barium enemas (501 mJ). The energy imparted by this modality is comparable to abdominal (57 mJ) and thoracic spine (55 mJ) examinations. The energy imparted concept, although rather crude in that it does not take into account the relative radiosensitivity of irradiated organs and tissues, serves as a useful indicator of the magnitude of the radiation dose delivered and is superior to the more conventional entrance skin dose as a risk parameter.

Finally, it is possible to calculate the contribution of lithotripsy radiation doses to the per caput dose (in the province of Manitoba, population 1 million) from diagnostic procedures that use ionizing radiation. Given an average effective dose-equivalent per patient of 0.75 mSv and an estimated 600 procedures per annum, the resultant collective dose associated with lithotripsy in Manitoba is 0.45 person-Sv. This corresponds to a per caput dose of 0.45 μSv. These values can be compared with the 25 000 nuclear medicine procedures [average patient H_E of 5.2 mSv and per caput dose of 130 μSv (Huda & Gordon, 1989)] and the 18 000 computed tomography scans [average patient H_E of 4.5 mSv and per caput dose of 81 μSv (Huda et al, 1989b)] currently performed in this province each year. Clearly, the introduction of lithotripsy will have a negligible impact on the per caput dose from diagnostic medical procedures.

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Asymmetric field arc rotations

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Abstract. Optimal treatment planning of target volume that surrounds a vital critical structure is often very difficult. Treatment techniques using moving beam therapy with fields asymmetric with respect to rotational axis of the collimator head allow treatment of such target volumes with minimal dose to critical structures. The availability of independent motion of the collimator jaws on new medical accelerators allows easy setting up of asymmetric treatment portals. Therefore, treatment techniques utilizing asymmetric field arc rotations with acceptable dose distributions have been possible.

It is sometimes necessary to treat a tumour volume that surrounds a structure with low radiation tolerance. One method that has been used in the past is to use moving beam therapy while a secondary block is placed in the field to shield the sensitive region (Proimos, 1960, 1961; Rawlinson & Cunningham, 1972; Takahashi, 1965). While it is possible to achieve acceptable dose distributions with this technique, there is the undesirable feature of significant transmission through field-shaping blocks. The safety concerns in rotating the machine gantry with heavy blocks and the weight of the blocks have been additional deterring factors.

A useful recent development in medical linear accelerators is the availability of field offset facilities (Varian, Siemens, USA; Philips, UK). This enables a photon field to be set with field centre offset from the radiation head rotation axis, thus allowing set-ups of asymmetric portals. This is achieved by independent motion of each collimator jaw or pair of jaws. Treatment techniques using moving beam therapy with fields asymmetric with respect to rotational axis are therefore very easy to implement. These are useful in the treatment of vertebral body and thyroid tumours. In both cases, the critical structure is the spinal cord. A doughnut-shaped isodose distribution is ideally suited for such target volumes. Such distributions are possible with asymmetric field arc rotations.

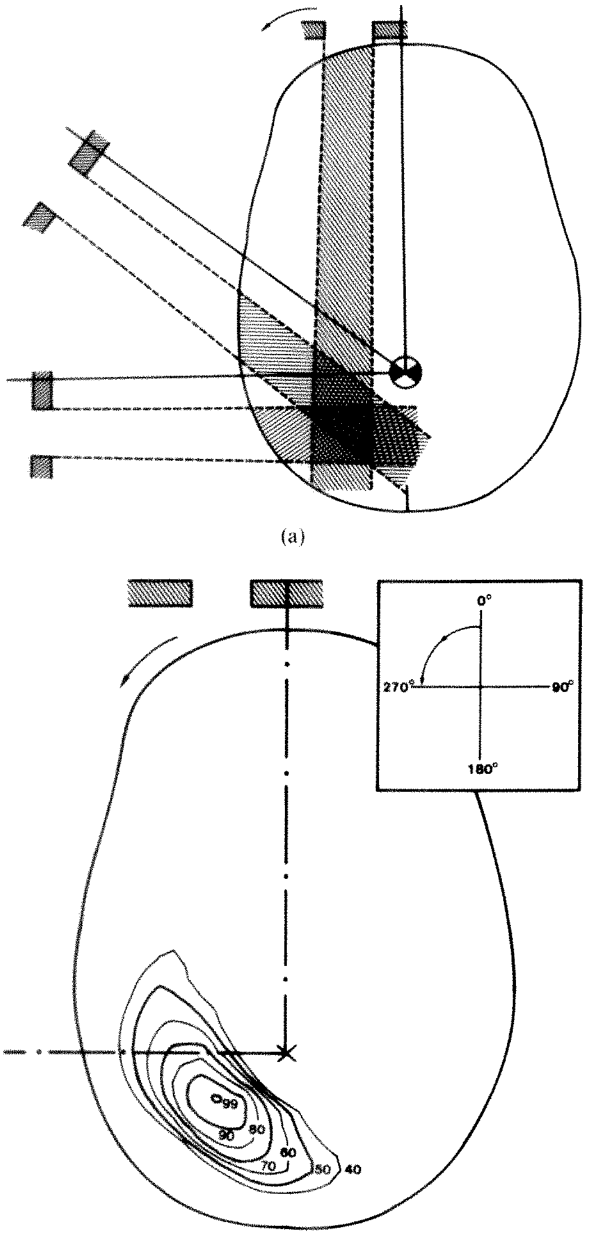
This report describes the concepts, computer simulation and experimental verification of asymmetric field arc rotations with a 6 MV X-ray beam from Philips SL75 linear accelerator. A clinical example is also described where it was possible to generate an optimized treatment plan with acceptable dose distributions for the management of a patient with a vertebral chordoma.

Concepts of asymmetric field arc rotation

It is important to understand the principle of beam summation for the generation of isodose curves for asymmetric field arc rotations. Conceptually, it is very different from symmetric arc rotation. Figure 1a illustrates how multiple asymmetric fields produce a high-dose area out of the arc sweep. This is different from the symmetric arc rotation where the high-dose area is within the arc sweep. Figure 1b shows isodose distribution for a 90° counter-clockwise arc rotation of a 2.5 cm wide field with a 1.5 cm offset of collimator jaws on a head contour. For asymmetric arc rotations, the patient contour, extent of rotation and the direction of field offset determine the location of high-dose areas. A 180° counter-clockwise rotation gives half doughnut-shaped isodose curves as shown in Fig. 2, which are orthogonal to the axis of rotation and lead the arc sweep by 90°. If the rotation is clockwise or the field offset is in the opposite direction, the isodose lines trail the arc sweep by 90°. Therefore, the direction of rotation and field offset are critical in asymmetric arc rotations except for a 360° rotation. The impact of surface contour on the location of the high-dose area when the field is offset for asymmetric arc rotation is illustrated in Fig. 3. A 360° arc rotation on the same head contour produces doughnut-shaped isodose distributions that have high dose located on the left side of the contour even though the contour has left–right symmetry. The reason for the high-dose area is the oblong shape of this contour in the anterior–posterior direction. The hot spot moves to the opposite half of the contour if the field is offset to the other side. The high-dose area for 360° rotation can be reduced by using another arc to spread out the dose more evenly. Figure 4 shows that by summing a 360° and a 130° arc rotation on this contour, uniform doughnut-shaped isodose distributions are possible. The isodose distributions in each example are normalized to the maximum dose in each case. The dose uniformity in the high-dose region can be controlled by modifying the dose profile of the beam further. One possibility is the addition of a wedge filter in the field. In the presence of wedge, the uniform dose region is enlarged and the dose fall-off in the shielded region is much sharper.

Computer simulation of asymmetric field rotations

Computer simulation of moving beam therapy is generally based on the superposition of dose



(a)

(b)

Figure 1. (a) Graphic illustration of high-dose area created by the summation of three isocentrically placed asymmetric fields on a head contour. (b) Isodose distribution for a 90° asymmetric arc rotation (2.5 cm wide field with 1.5 cm field offset on a head phantom). The high-dose area is located outside the arc sweep.

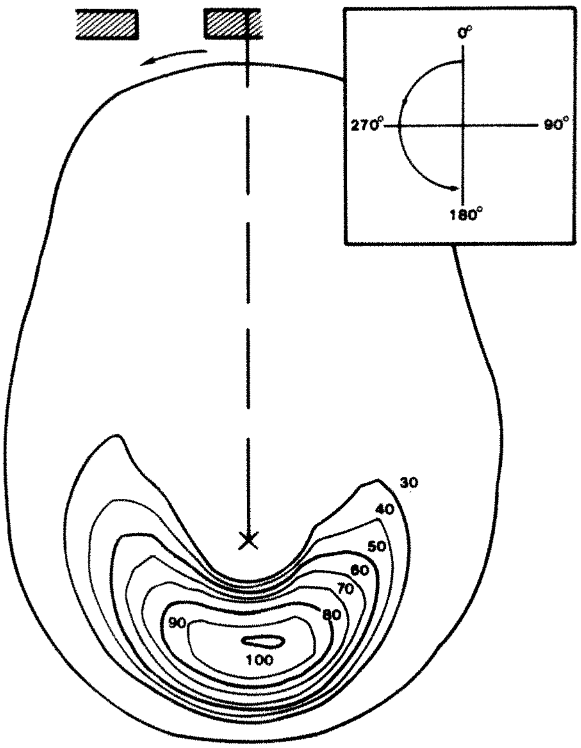


Figure 2. Half doughnut-shaped isodose curves for 180° counter-clockwise asymmetric arc rotation (2.5 cm wide field with 1.5 cm field offset on a head phantom).

distribution from fixed fields spaced at equal angular intervals around the axis of rotation. All computer-based treatment planning systems have software for producing dose distributions for rotation therapy. Asymmetric field rotation simulation is based on the same concept except that a part of the fixed field is blocked. The amount of blocking required is dependent on the magnitude of field offset. It has been shown by Khan et al (1986) and Palta et al (1988) that asymmetric fields can be simulated in a computer algorithm as a blocked beam. Therefore, the asymmetric arc rotation was simulated on our treatment-planning computer system by summation of discrete stationary beams with blocks. The computational software on our VAX-based treatment-planning system is similar to that described by Cunningham (1977). The primary dose is described by divergence, attenuation, an off-axis beam profile and an empirically determined penumbra function. The scatter dose is calculated by scatter integration using scatter/air ratio (SAR) values. The SAR values are derived from measured depth–dose data. The beam profile calculated using the empirical penumbra function matches well with the experimentally measured beam profile. No corrections are used for tissue heterogeneities. Thirty-six beams were used to simulate 360° rotation. Further increase in the number of beams does not alter the calculated doses by more than a few per cent but the computational time increases significantly.

Experimental measurements

The accuracy of the treatment-planning software for asymmetric rotation was checked using

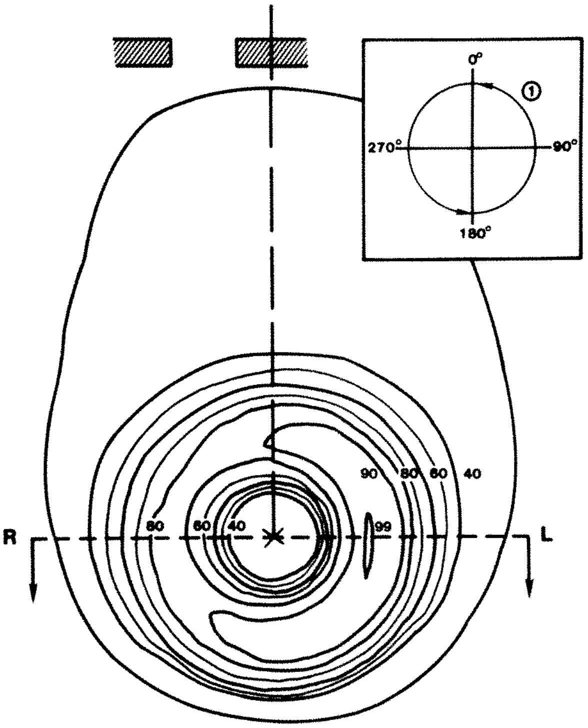


Figure 3. Doughnut-shaped isodose curves for 360° counter clockwise rotation of same asymmetric field. Hot spot on left side is due to the non-uniform surface contour of the head phantom.

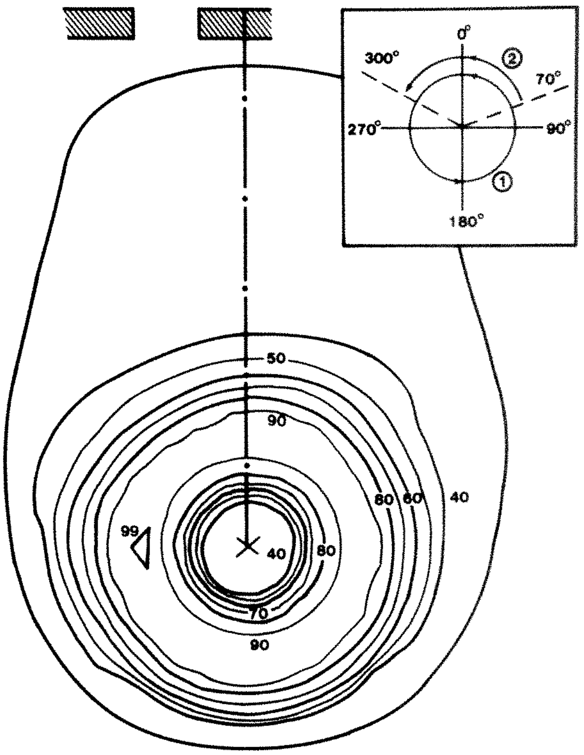


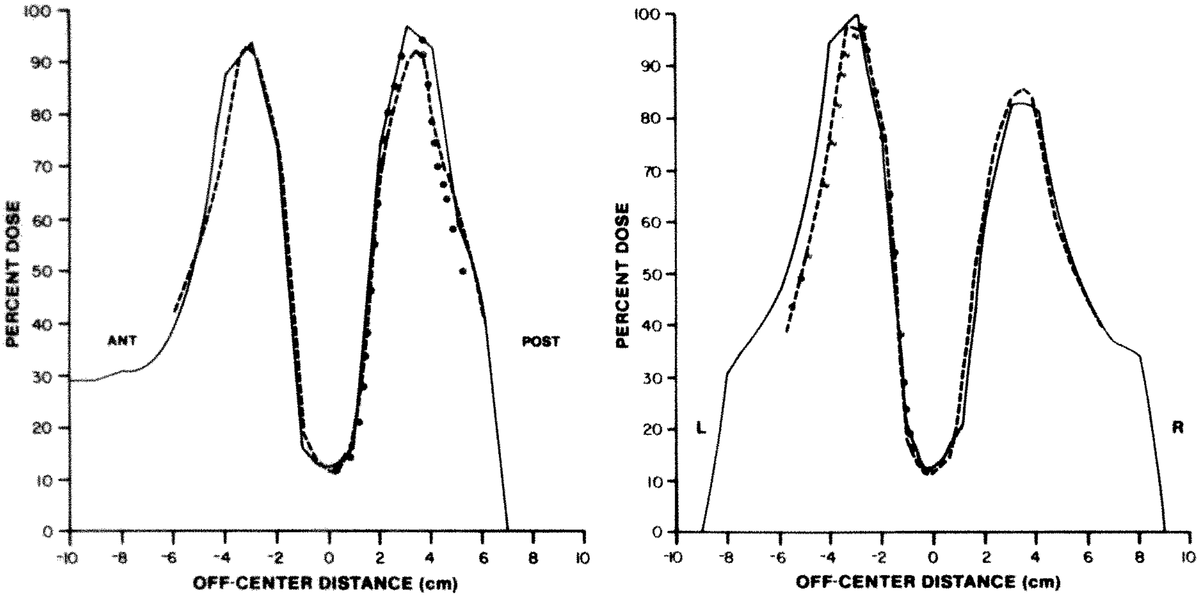
Figure 4. Two-arc asymmetric rotation to achieve uniform doughnut-shaped isodose distribution for the plan in Fig. 3. Beam weighting factor for 360° rotation (Arc 1) is 1, and for 130° rotation (Arc 2) is 0.1.

thermoluminescent dosemeter (TLD)-100 chips, which are 3.2 mm × 3.2 mm and 0.89 mm thick, and Kodak ready-packed XV-2 film in an anthropomorphic phantom. The TLD chips were individually calibrated on a 6 MV X-ray beam and the recommended annealing procedures were followed. A sensitometric curve for XV-2 type film was generated to analyse data obtained from the film measurements. The TLDs were placed in the central transverse slice of an anthropomorphic head phantom. The film, cut to size, was also sandwiched between two slices of the phantom in the centre of the radiation field. The phantom was irradiated based on a 360° asymmetric field (2.5 cm wide × 6 cm with 1.5 cm field offset) rotation plan. Each film was then scanned by the computer-controlled densitometer and programs were run to convert optical density to dose. Figure 5 shows dose profiles across two orthogonal axes of the transverse slice of the head phantom. These profiles are obtained from computer simulation of the asymmetric rotational plan and film scanning. Also shown on the scans are the point dose measurements with TLDs. The measured data agree well with the computer prediction except for the central cold area where computer calculations overestimated the scattered dose under the block. Mohan and Chui (1987) and Starkschall (1988) have also identified similar inaccuracies by the traditional scatter integration approach near the boundaries defined by blocks or collimators. They propose convolution techniques to improve accuracy of calculations near the boundaries. These techniques are still under development and are not available for routine treatment planning.

Clinical example

A treatment plan for a patient with a chordoma of the third lumbar vertebra is presented to illustrate the use of asymmetric field arc rotation. This patient was prescribed to receive 60 Gy post-operatively to a volume that included the 2nd to the 4th lumbar vertebrae as well as laminae and pedicles. A treatment plan was generated that included an anterior and a posterior opposing field for a total dose of 40 Gy. A boost plan with two overlapping asymmetric arc rotations was used to limit the dose to the spinal cord and roots to less than 50 Gy. The dose to the lower pole of the kidneys was less than 8 Gy. The torso of an anthropomorphic phantom was used to simulate this treatment plan for experimental verification.

The beam orientation and isodose distribution for the boost plan is shown in Fig. 6. It is based on two asymmetric arc rotations with 1.5 and 3.5 cm wide fields. The field offset for each arc is 1 cm. The phantom, with a XV-2 film placed in the central transverse plane,



(a) (b)

Figure 5. Dose profile through isocentre for a 360° asymmetric rotational plan shown in Fig. 3. (———) Computer data; (– – –) film data; (●) TLD data. (a) Anterior–posterior dose profile and (b) left–right dose profile.

was irradiated based on this treatment plan. Figure 7 shows a dose profile through the spinal cord for the computer-generated plan and the measured data with film.

Thyroid cancer where the tumour volume includes both the thyroid gland and the cervical and upper mediastinal lymph nodes has also been treated with plans using asymmetric arc rotations for small boost volume after cord tolerance has been approached. Conventional treatment, which is given through parallel, opposed portals with a central block added to limit the cord dose below tolerance is inadequate because of the non-uniformity of the dose in the target volume. In contrast, asymmetric arc rotation delivers uniform dose to the whole of the target volume while limiting the dose to the spinal cord. An optimized plan using asymmetric arc rotation reduces the overall cord dose significantly, and allows a high dose to be given homogeneously to the tumour volume.

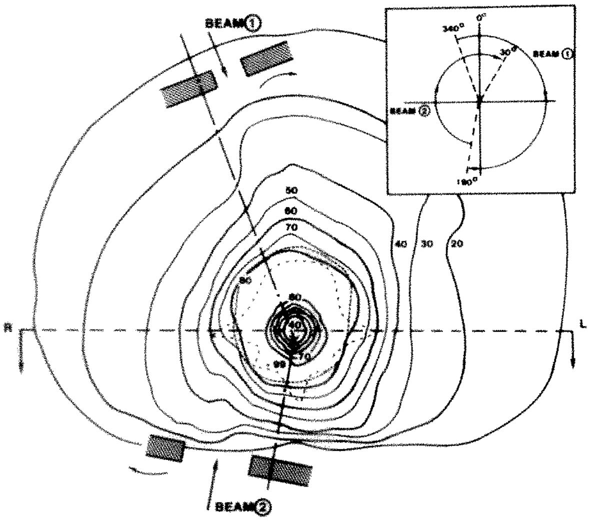


Figure 6. Isodose distribution for a two asymmetric field arc rotation for the treatment of chondroid chordoma of the 3rd lumbar vertebra.

Discussion and conclusion

Asymmetric motion of the collimator jaws, available with new medical linear accelerators, is primarily being

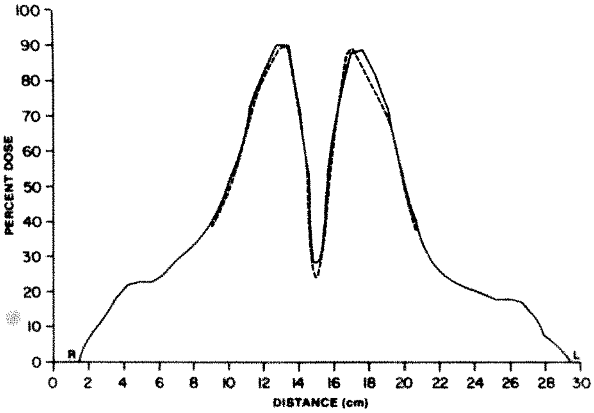


Figure 7. Dose profile through the spinal cord for the plan shown in Fig. 6; (———) computer data, (– – –) film data.

used to set treatment portals with little or no divergence at one edge of the field. This alleviates problems of non-uniform dose distributions in the field match region. The facility of asymmetric jaws is also very helpful in developing simple rotational treatment techniques with asymmetrically placed fields. We have attempted to show that such techniques are useful in the treatment of areas that surround critical structures. The only limitation of this technique is that the target volume can only be approximated by a cylinder of arbitrary cross-section whose axis is parallel to the long axis of the patient. Therefore, this technique is limited to small target volumes. Complex target volumes will require continuous movement of several treatment parameters. The computer simulation of asymmetric fields does not require modifications to the algorithms. Therefore, these techniques are easily implementable for boost therapy of certain target volumes.

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Variation of tumour radiosensitivity with time after anaesthetic

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Abstract. Transplanted C_3H mouse mammary tumours were given single doses of X irradiation in air or oxygen at 1 atmosphere (atm) with or without anaesthesia of the recipient mice by ketamine and diazepam. The radiation response to single doses of 25 Gy was determined in terms of the time taken to reach 3.5 times the treatment volume. Under all conditions there was more growth delay in tumours irradiated in pure oxygen than in air. In both air and oxygen, the radiation response for anaesthetized animals tended to fall below the level for non-anaesthetized ones when only 10 min had elapsed after the administration of anaesthesia. After 25 min, the response in air was back to the level for the non-anaesthetized animals but the oxygen group now showed significant sensitization compared with the oxygen without anaesthetic group. After 40 min, the air group now showed slight sensitization and the oxygen group still showed significant sensitization by the anaesthetic. These results demonstrate the importance of the time interval between anaesthesia and irradiation of mouse tumours.

Anaesthesia is commonly used in mouse tumour radiobiology to enable the animals to be immobilized during irradiation. It has been known for several years that anaesthesia can change the radiosensitivity of normal and malignant tissues. Several authors have studied these effects, but their results show a confusing picture with some demonstrating a significant protective effect, some showing no effect and some showing significant sensitization (Denekamp et al, 1979; Sheldon & Chu, 1979). The time interval was not studied.

It is generally agreed that anaesthetized mice treated while breathing pure oxygen at normo- or hyperbaric pressure invariably show a significant increase in tumour radiosensitivity above non-anaesthetized controls (Milne et al, 1973; Suit et al, 1979). This was shown in our laboratory (Tozer et al, 1984) when mice were given single doses of X rays. Anaesthesia increased tumour cure by a dose-modifying factor of 1.5 in hyperbaric oxygen but not in air. The time interval between anaesthesia and irradiation was ~10 min in air but ~30 min in hyperbaric oxygen to allow for pressurization.

It seems likely that anaesthesia may have a variety of effects on radiosensitivity depending on the plane of anaesthesia at the time of treatment and that this will depend on the time interval between the induction of anaesthesia and irradiation. One effect of anaesthesia in the mouse is a lowering of core temperature and we have previously reported (Nias et al, 1986) the effects of such hypothermia on tumour blood flow, oxygen concentration and radiosensitivity under hyperbaric oxygen conditions. More recently, we have shown (Nias et al, 1988) that cellular oxygen metabolism is reduced by anaesthesia (as well as by hypothermia) but that because the blood supply to our mouse tumours is maintained under such conditions, their radiosensitivity is increased, perhaps because of an increase in oxygen diffusion distance.

In the present work we have studied the radiosensitivity of tumours at various time intervals after the start of anaesthesia in mice breathing oxygen or air at 1 atmosphere (atm). The pre-irradiation breathing time (PIBT) is shown to be a less important factor than this anaesthetic effect. A preliminary report of this work has been published (Perry & Nias, 1988).

Materials and methods

A serially transplanted line of C_3H mouse mammary adenocarcinoma (Nias et al, 1980) was used in SPF-derived inbred C_3H mice. Single doses of 250 kVp X rays (0.83 mm Cu half-value thickness) were delivered at 200 cGy/min to mice breathing air or normobaric oxygen in the chamber used for hyperbaric oxygen studies (Tozer et al, 1984), with all but the tumour shielded by 2 mm of lead. Ketamine (45 mg/kg) and diazepam (0.5 mg/mouse) anaesthesia was used and the mice then became hypothermic (Nias et al, 1986). Tumour volume was determined from three perpendicular measurements and growth expressed in terms of the mean (and standard error (SE) of the mean) time taken by a group of tumours to reach 3.5 times the treatment volume, which was approximately 200 mm^3. The sizes of individual tumours were related to their individual treatment volumes. (For unirradiated tumours the time to reach 3.5 times the treatment volume was ~6 days for animals breathing both air and oxygen, with or without anaesthesia.)

The response was measured in animals irradiated 10, 25 or 40 min after the administration of anaesthesia. It was also measured in animals that were not anaesthetized but were irradiated after equivalent PIBT.

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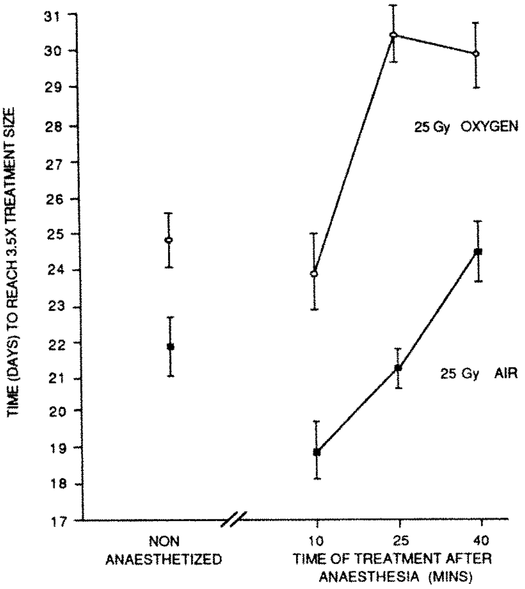

Figure 1. Growth delay of C_3H mouse mammary tumours treated in air or normobaric oxygen either without anaesthesia or with anaesthesia given at different time intervals before irradiation. Values are shown as the mean and SE of the mean.

At least 10 animals were used for each experimental point. The time intervals indicate the beginning of the radiation dose. To allow time for anaesthesia, oxygen breathing did not begin until 10 min in Fig. 1, but was at zero time in Fig. 2. Statistical comparisons were made using Student's *t*-test.

Results

Figure 1 shows the data pooled from two separate experiments that gave very similar results. As might be expected, there was more growth delay at all times by tumours given 25 Gy when the animals breathed pure oxygen rather than air. In both cases this radiation response showed a reduction below the level for non-anaesthetized control mice when a time interval of only 10 min had elapsed after the administration of anaesthesia. In the case of mice irradiated in air, this was a significant reduction in radiation response ($p=0.0014$).

After 25 min, the response in air had returned to the control level but the oxygen group now showed a highly significant increase in response ($p=0.00002$), which was maintained at 40 min. At that time, the air group also showed an increase in response that was just significant ($p=0.0497$). Thus, in comparison with the non-anaesthetized control animals, tumours irradiated in anaesthetized animals showed some radiation protection at 10 min after the administration of anaesthesia, when they had begun breathing normobaric oxygen; they also showed radiosensitization at 25 and 40 min. This pattern was shown to a lesser extent by tumours irradiated in mice breathing air.

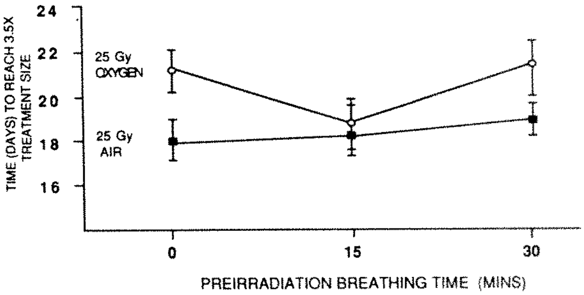

Figure 2. Growth delay of C_3H mouse mammary tumours treated in air or normobaric oxygen after different time intervals. Values are shown as the mean and SE of the mean.

In a third experiment, none of the mice were anaesthetized. Although the absolute levels of regrowth delay were lower than those shown in Fig. 1, the relative levels showed no significant variation in tumour response at equivalent time intervals (Fig. 2). These time intervals are comparable to those shown in Fig. 1, after allowing 10 min for the induction of anaesthesia.

Discussion

These studies have shown that there can be a considerable variation in the radiosensitivity of C_3H mouse mammary tumours depending on the time interval after the induction of anaesthesia, particularly if the animals are breathing oxygen. The PIBT of oxygen does not contribute to this pattern since the animals showed no such change in tumour radiosensitivity if they were not anaesthetized.

Some authors have attributed the difference in radiation response to the oxygen PIBT but, of necessity, this time period is also the post-anaesthetic period. The question arises whether it is the period of anaesthesia (and hypothermia), the period of oxygen breathing or both that leads to an increase in radiosensitivity. Siemann et al (1977) found much more variation in the radiosensitivity of KHT sarcoma with oxygen PIBT when their mice were anaesthetized, possibly because the anaesthetic prevented the vasoconstrictive effect of oxygen.

When we tried to separate the effects of oxygenation from the effects of anaesthesia and hypothermia, we found that the radiation response of our C_3H mouse mammary tumour under hyperbaric oxygen was increased much more when anaesthesia was used and that it made no difference whether the anaesthetized mice were normothermic or hypothermic (Nias et al, 1986). In both cases, the time interval between the induction of anaesthesia (by ketamine and diazepam) and irradiation was 30 min. Thus, this time interval seems to be optimal under such conditions.

Most studies of the effect of anaesthesia on tumour radiosensitivity have involved shorter time intervals. Thus Sheldon and Chu (1979) found protection of their MT mouse tumour when irradiated 10 min after sodium pentobarbitone or chloral hydrate anaesthesia and no effect with tribromoethanol or fentanyl, fluanizone, diazepam anaesthesia. Similarly, Denekamp et al (1979) found protection of three of their mouse tumours when irradiated 10 min after sodium pentobarbitone, although one other tumour showed sensitization. Therefore, both these observations showed radiation protection when irradiation was given 10 min after the induction of anaesthesia, just as we have found in the present study.

Longer time intervals would not be considered necessary in the normal way and it might even be thought to be deleterious to experimental animals to prolong anaesthesia for no good reason. But when hyperbaric oxygen is being used it is necessary to raise the pressure slowly and then "soak" the tissues at the higher oxygen tension for a period before irradiation. This was why Tozer et al (1984) had to wait 30 min before treating their mice under hyperbaric oxygen. They then found that anaesthesia sensitized their tumours to radiation, just as we have now found with normobaric oxygen after 25 min.

The question arises of what mechanisms may explain these contradictory responses to radiation under anaesthesia and whether they can be exploited. We have observed that anaesthetized mice become hypothermic so that by 30 min after the induction of anaesthesia, the temperature had fallen from 37 to 30°C (Nias et al, 1986). Under these conditions one can expect a reduction in the rate and depth of respiration, a fall in cardiac output and a reduction in cellular oxygen metabolism. There may also be changes in tumour blood flow but it is difficult to measure this without using invasive techniques. Menke and Vaupel (1988) used the ^{85}Kr clearance technique to measure tumour blood flow in the rat with a variety of anaesthetic analgesic and sedative agents, including ketamine and diazepam (but not in combination).

We have shown by Clark electrode studies *in vitro* that oxygen metabolism is not only reduced by such hypothermia but also by anaesthetic drugs (Nias et al, 1988). It might have been expected that the blood supply to a tumour would be reduced by hypothermia and that the hypoxic fraction of tumour cells might be increased. However, we have shown by ^{133}Xe and ^{86}Rb studies that under hypothermic conditions the blood supply to the tumour *is* maintained (Nias et al, 1986, 1988) and as a result the hypoxic fraction of the tumour is reduced and radiosensitivity increased. These observations with hyperbaric oxygen necessitated a 30-min post-anaesthesia time interval. But shorter time intervals are usually employed for studies with normobaric oxygen.

Normobaric oxygen has sometimes been assumed to be less effective than carbogen because of the work of Du Sault (1963). However, she used spontaneous C_3H mouse mammary tumours varying between 8 and 19 mm in diameter, much larger than the transplanted tumours used in the present study. Furthermore, her mice were irradiated immediately after flushing the chamber with carbogen. In subsequent studies, Suit et al (1972) found that normobaric oxygen was a more effective environment for irradiation than both air and carbogen, particularly if the PIBT was 15 min and anaesthesia was used. Milne et al (1973) found that normobaric oxygen was as effective as carbogen in sensitizing mouse tumours so long as the PIBT was 15 min, again with anaesthesia. More recently, Mueller-Klieser et al (1983) have used their cryobiopsy technique to compare tumour oxygenation after exposure to air or oxygen at various pressures. There was a marked increase even with oxygen at 1 atm. But these estimates were made after 30 min oxygen breathing and anaesthesia.

Our data may explain the variable responses reported in the literature by authors who used a short time interval after anaesthesia, before the physiological parameters that determine tumour blood supply and oxygenation have become optimal with respect to radiosensitivity. The data also show that effective radiosensitization of tumours may then be obtained in mice breathing normobaric oxygen.

Acknowledgments

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Technical note

A method for estimating embryo doses resulting from computed tomographic examinations

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In 50% of all cases of pregnant patients undergoing computed tomographic (CT) examinations of the pelvic region, an embryo dose value of 20 mGy will be exceeded. This was revealed in a field study on dose values and related data conducted during 1986 and 1987 in the Federal Republic of Germany, which covered 122 facilities, about one-fifth of all the installations operated at that time in the country (Panzer et al, 1989). In the Federal Republic of Germany, an embryo dose value of 20 mGy is considered as an investigation level (Leppin, 1979) in order to ensure that significantly higher values, which might indicate an interruption of pregnancy, do not fail to be noticed. Thus there exists an occasional need to estimate individual embryo doses, and in some cases to go further and make more detailed determination of the dose. Values reported in the literature are of little help in this context because it is unlikely that they were obtained under similar exposure conditions as the examination under question. In CT examinations there is a large variability in length and site of the scanned body region, the X-ray output and special techniques such as repeats of interesting sections with higher resolution or contrast media. Apart from anatomical differences between patients, the variety of the exposure conditions makes it impossible to determine and report embryo dose values that might hold true for all possible situations. Therefore, for the determination of embryo dose it remains necessary to simulate the examination under question and to study the impact of inevitable uncertainties by irradiating a patient-like phantom and measuring doses at the assumed position of the uterus. However, because of the time needed and a lack of suitable equipment, this procedure is restricted to very few institutes.

Methods

The method used to determine embryo doses described in this paper is based on the results of Monte Carlo calculations using a "female mathematical reference phantom" (height 160 cm, weight 60 kg, diameters of the elliptical trunk 19 and 38 cm). A more detailed description of the phantom and its organs and the Monte Carlo calculation is given by Kramer et al (1982). The results consist of conversion factors (f_i) that describe the mean dose to an organ or tissue (i) per unit reference dose. In the case of CT examinations, this reference dose is the absorbed dose free in air on the axis of rotation. The mean dose (D_i) to an organ or tissue (i) then follows the relation:

$$D_i = f_i \times D_a \tag{1}$$

where D_a is the dose value on the axis of rotation that appears in the examination considered. The values of f_i to be used in Equation 1 depend on field size, field position, direction of the beam and the radiation quality (tube voltage, filtration).

In Table I, values for $f_{\text{uterus},z}$ (in the following called f_z) are listed, which express the mean dose to the uterus resulting from a single 1 cm scan across the phantom at height z (z is given in centimetres in the direction of the length axis of the phantom with its origin at the lower end of the trunk and coinciding with the axis of rotation). The values f_z were calculated for the following.

1. Rotate-only CT systems without beam shaping devices between focus and patient.
2. Three radiation qualities:
   (A) 125 kV, 2.2 mm Al + 0.25 mm Cu, mean photon energy: 64.5 keV, half-value layer (HVL): 8.03 mm Al;
   (B) 125 kV, 2.2 mm Al + 0.40 mm Cu, mean photon energy: 68.9 keV, HVL: 9.46 mm Al;
   (C) 120 kV, 6.0 mm Al, mean photon energy: 58.7 keV, HVL: 6.09 mm Al.
3. A scan angle of 360°, which, in the field study (Panzer et al, 1989), was found to be by far the one most often used.
4. A focus to axis of rotation distance of 76 cm.
5. A field size in this distance of 40 cm × 1 cm; thus the fan beam encompasses totally the cross-section of the phantom in all projections.
6. Vertical incidence of the fan beam with regard to the length axis of the phantom.

The mean uterus dose D_u can be calculated by means of the factors f_z from Table I for CT examinations using the relation:

$$D_u = D_a \times \sum_{z_1}^{z_2} f_z \tag{2}$$

Table I. Factors (f_z) to convert dose free in air on the axis of rotation into uterus dose for single slices of 1 cm width across the female mathematical phantom in height z (z indicates the bottom of the slice)

Height (cm) in mathematical phantom (z)	f_z			Approximate anatomical landmarks
	A	B	C	
	0.001	0.002	0.001	
30	0.002	0.002	0.001	
	0.002	0.002	0.001	lumbar vertebra 3
	0.002	0.003	0.002	
	0.003	0.003	0.002	
	0.004	0.004	0.003	lumbar vertebra 4
25	0.004	0.005	0.003	
	0.005	0.006	0.004	
	0.006	0.007	0.005	lumbar vertebra 5
	0.008	0.009	0.006	
	0.010	0.011	0.008	
20	0.012	0.013	0.009	
	0.014	0.016	0.011	
	0.016	0.019	0.013	
	0.020	0.024	0.016	
	0.026	0.029	0.021	sacrum
15	0.031	0.036	0.026	
	0.057	0.064	0.048	
	0.093	0.104	0.079	
	0.091	0.100	0.075	
	0.046	0.051	0.039	
10	0.032	0.034	0.025	
	0.025	0.027	0.020	coccyx
	0.020	0.022	0.017	
	0.016	0.019	0.013	
	0.013	0.015	0.011	
5	0.011	0.013	0.009	tub. ischii
	0.009	0.011	0.008	
	0.008	0.008	0.006	
	0.006	0.007	0.005	end of trunk
	0.005	0.006	0.004	
0	0.004	0.004	0.003	
	0.003	0.004	0.002	
	0.003	0.003	0.002	
	0.002	0.003	0.002	legs
	0.002	0.002	0.001	
−5	0.001	0.001	0.001	
	0.001	0.001	0.001	

A, B and C are the three radiation qualities listed in the text.

where z_1 and z_2 describe the boundaries of the scanned region (rounded to integer centimetre values). Examinations can be analysed in one step by using Equation 2 as long as the dose on the axis remains constant. Sections in which D_a is changed should be treated separately and the resulting values of D_u for each section should be summed to give the total value for the whole examination.

For a better orientation when applying the values from Table I, approximate positions of anatomical landmarks are indicated.

Absorbed dose in air on the axis of rotation

Figure 1 shows the distribution of 494 normalized values for the dose free in air on the axis of rotation as found in the field study (Panzer et al, 1989), which

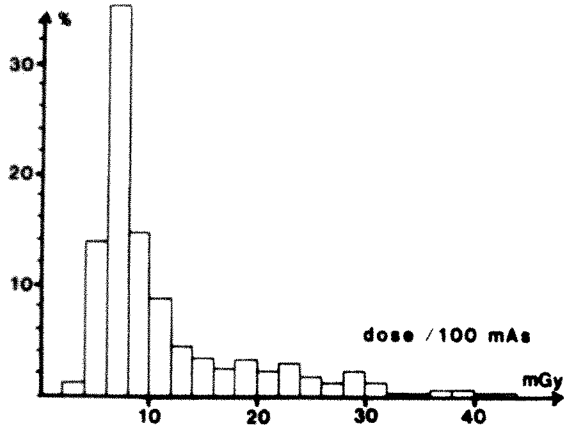

Figure 1. Distribution of 494 normalized dose values occurring under routine conditions for a single scan free in air on the axis of rotation (100 mAs, 76 cm focus to axis distance).

includes all makes and models, filtrations and tube voltages between 120 and 130 kV without beam-shaping devices between focus and patient. Comparison with the values in Table II demonstrates that only a rough or tentative estimation of embryo dose can be obtained using values of D_a from the literature in Equation 2. Because of discrepancies between nominal and real values for tube voltage, mAs-product, filtration and anode roughening, etc., the dose values occurring in practice may differ markedly from reported values. Also, the expected dependence on tube voltage and filtration is totally masked by these effects. This emphasizes the necessity to base reliable dose estimations on dose measurements at the respective facility, as well as considering the impact of geometric effects like overlapping (intended or due to poor adjustment of the collimating system) of adjacent slices or spaces between consecutive slices on the average value for D_a to be entered in Equation 2.

Sources of errors and limitations of the method

In general, the application of this method is restricted to patients in the early stage of pregnancy (*i.e.* within the first 2 months), as long as size and position of the uterus is not altered dramatically by the growing conceptus.

Small variations in the examination parameters (focus to axis distance between 65 and 85 cm, parallel shift of the phantom axis against the axis of rotation up to some centimetres or 0.2 mm of copper instead of 0.25 mm in quality A) do not have significant impact on the calculated f_z values. For radiation qualities other than A, B or C, the error of f_z can be estimated or compensated by interpolation, using the mean photon energy or the HVL of the radiation quality in question.

Statistical errors introduced by the Monte Carlo method range from 1.3% (for slices across the uterus) to 9% (for slices at both the ends of the region considered in Table I).

Systematic errors from simulating the physical events in an anthropomorphic phantom by a Monte Carlo code cannot be analysed quantitatively. However, there is evidence that these errors, in general, are below 10% and do not exceed 15%. This statement is based on preliminary results comparing measured dose values at 28 sites on an Alderson phantom undergoing CT examination with corresponding values calculated for a three-dimensional mathematical reconstruction of the same Alderson phantom (Panzer et al, manuscript in preparation).

Embryo dose is regarded as being equal to the mean dose to the uterus. The maximum error due to this simplification will arise when a boundary of the scanned body region coincides with the position of the uterus, thus causing a dose gradient across the organ with the consequence that the mean dose to the uterus and the embryo differ. A rough estimation of this effect is possible by calculating the difference between the resulting doses to the uterus when the scanned region in Table I is tentatively shifted one line higher and one line lower with regard to the assumed position. By a similar procedure, errors due to supposed differences between the axial position of the uterus in the phantom and in a patient can be estimated.

Since the depth–dose curves resulting from 360° scans are very flat or horizontal near the centre of the patient or phantom, errors due to discrepancies in the radial position of the uterus in the phantom and patient remain small. Measurements in an Alderson phantom demonstrated that they are <3% for a 1 cm shift within a distance of 6 cm from the centre.

Errors resulting from different sizes of phantom and patient could not be studied directly because this would

Table II. Values from the literature for the dose free in air at 76 cm distance normalized to 100 mAs

Tube voltage (kV)	Filtration (mm)	Dose (mGy)	Reference
100	2.2 Al + 0.25 Cu	7.3	Mika & Reiss (1969)
120	5.0 Al + 0.50 Cu	6.7	Birch et al (1979)
120	6.0 Al	14.0	Wachsmann & Drexler (1976)
120	6.0 Al	14.8	Mika & Reiss (1969)
125	2.2 Al + 0.25 Cu	12.8	Mika & Reiss (1969)
125	2.2 Al + 0.40 Cu	9.6	Mika & Reiss (1969)
125	2.2 Al + 0.40 Cu	11.0	Birch et al (1979)

have meant the construction of new phantoms. A comparison of calculated conversion factors f_p for the pancreas (an organ rather similar to the uterus in terms of volume and central position in the phantom and embodied in both mathematical phantoms) for a CT examination of the male phantom (70 kg; diameter of the elliptical trunk 20 and 40 cm) and the female phantom (60 kg; 19 and 38 cm diameter) shows a decrease in organ dose of 7% for the larger phantom ($f_p = 0.55$ for the female phantom and $f_p = 0.51$ for the male (Drexler et al, 1985)). This value can be used to estimate the error resulting from size differences and, depending on the accuracy demanded, it also indicates the limitations for applying the values from Table I to an individual patient.

A further limitation is due to the fact that the Monte Carlo calculation cannot simulate situations in which the length axis of the phantom is not parallel to the axis of rotation. In the case of frequent examinations of the lumbar spine, however, where the axis of the patient is just slightly tilted to compensate for the physiological lordosis and where the contribution from these tilted slices to the dose to the uterus are comparatively small, this effect can be ignored.

Acknowledgment

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Case reports

Primary malignant fibrous histiocytoma of a metacarpal bone: a new localization

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Malignant fibrous histiocytoma (MFH) is a common tumour of the soft tissues (Ros et al, 1984); it is rare in bone but the predilection sites in bone are the distal metaphysis of the femur and the proximal metaphysis of the tibia. We present a patient with MFH of a metacarpal bone.

Case report

A 72-year-old man presented with pain in his right second metacarpal region. Duration of symptoms was 5 months with increasing swelling in the past 4 weeks. There was no history of previous trauma or malignancy. Clinical examination revealed a tender second metacarpal of the right hand. Laboratory tests including a white blood cell count and sedimentation rate were normal. A radiograph of the right hand showed an expanding, osteolytic lesion of the second metacarpal bone with cortical destruction and extensive periosteal reaction (Fig. 1). There was no evidence of pathological fracture. Angiography showed a hypervascular tumour with signs of malignant neovascularity and intense parenchymal stain (Fig. 2).

Whole-body scintigraphy and a radiographic bone survey disclosed no additional lesions. The chest radiograph was normal.

Open biopsy produced numerous fragments of solid tumour tissue. Histological examination showed a high-grade, pleomorphic sarcoma, the tumour cells being arranged in a storiform pattern and producing varying amounts of collagen (Fig. 3). In addition to the striking degree of pleomorphism of the tumour cells, numerous mitoses were present, many of which were abnormal. Numerous giant cells were distributed throughout the specimens but no osteoclast giant cells were seen. The appearances were typical of a malignant fibrous histiocytoma of bone.

Discussion

Malignant fibrous histiocytoma of bone was described by Feldman and Norman in 1972. The number of published cases has since exceeded 220 (Freyschmidt et al, 1981; Bacci et al, 1985; den Heeten et al, 1985; Nakashima et al, 1985; Yuen & Saw, 1985) with a slight male predominance (60:40) (Dunham & Wilbourn, 1979; Freyschmidt et al, 1981). The peak incidence of the tumour is in the fifth and sixth decade (Kahn et al, 1978) with a reported range from 7 (Huvos, 1976) to 79 years (Feldman & Lattes, 1977). The most common locations are the distal metaphysis of the femur and the proximal metaphysis of the tibia (Dahlin et al, 1977; Freyschmidt et al, 1981). Less common sites are the proximal diaphysis of the femur, the iliac bone, skull, ribs, sternum, mandible and scapula (Dahlin et al, 1977; Freyschmidt et al, 1981). A metacarpal location

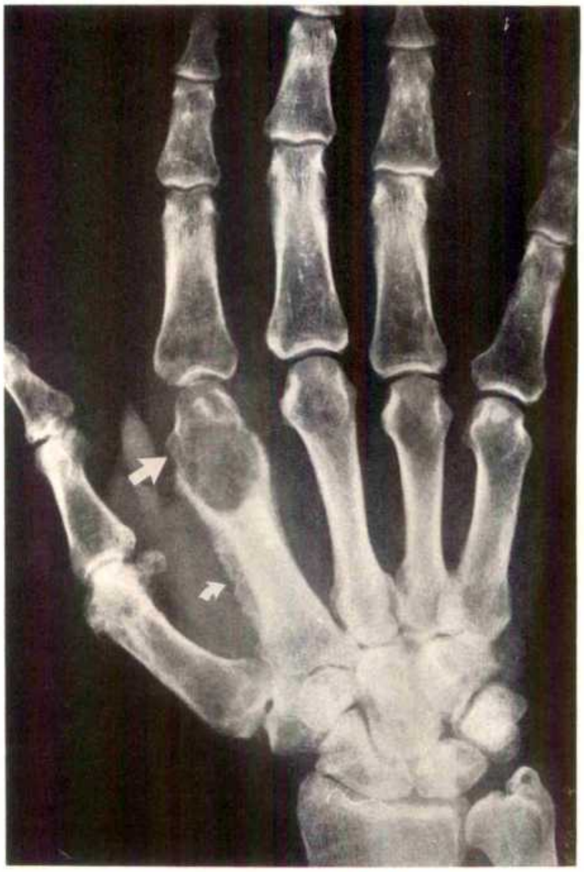

Figure 1. A plain radiograph of the hand shows an osteolytic, expanding lesion of the second metacarpal bone with cortical destruction (arrow) and periosteal reaction (curved arrow). There is no evidence of pathological fracture.

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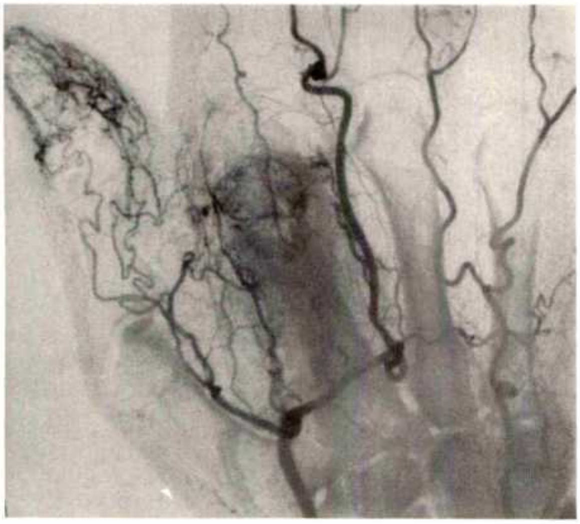

Figure 2. A selective angiogram shows a hypervascular lesion corresponding to the area of bone destruction.

to our knowledge has never been reported before. Occasionally, the tumour originates in sites of underlying bone disorders, such as infarction, previous radiation therapy, Paget's disease or enchondroma (Galli et al, 1978; Dunham & Wilborn, 1979; Freyschmidt et al, 1981; Bacci et al, 1985). McCarthy et al (1979) have reported four cases of multicentric MFH of bone.

Clinically, MFH of bone presents as a slow-growing, moderately painful lesion with increasing swelling over several months (Dunham & Wilbourn, 1979; Freyschmidt et al, 1981; Yuen & Saw, 1985). Pathological fractures are frequent (Feldman & Norman, 1972; Dunham & Wilbourn, 1979).

The radiographic features are those of an osteolytic lesion. Typically, the cortex is eroded and expanded. Periosteal reaction—particularly as extensive as in our case—is unusual (Feldman & Norman, 1972; Spanier et al, 1975; Kahn et al, 1978; Dunham & Wilbourn, 1979). One explanation for this atypical appearance could be an extensive reaction to a pathological fracture, but this could not apply in our case.

The radiological changes are non-specific. The differential diagnosis includes metastasis from an occult primary tumour, fibrosarcoma of bone, osteolytic osteosarcoma, primary malignant lymphoma and malignant giant cell tumour.

Histologically, the tumour is composed of fibroblast-like and histiocyte-like elements that are spindle-shaped and typically arranged in a storiform pattern. Multinuclear giant cells of Touton type and tumour giant cells may also be found (Yao-Shi et al, 1975; Guarnaschelli et al, 1979; Nakashima et al, 1985).

The treatment of choice is surgical, *en bloc* resection of the tumour. Adjuvant chemotherapy as well as radiation therapy seem to be beneficial for long-term survival (Spanier et al, 1975; Dahlin et al, 1977; Dunham & Wilbourn, 1979). Den Heeten even postulated that the treatment of choice should be chemotherapy and that surgery should be regarded as adjuvant therapy (den Heeten et al, 1985).

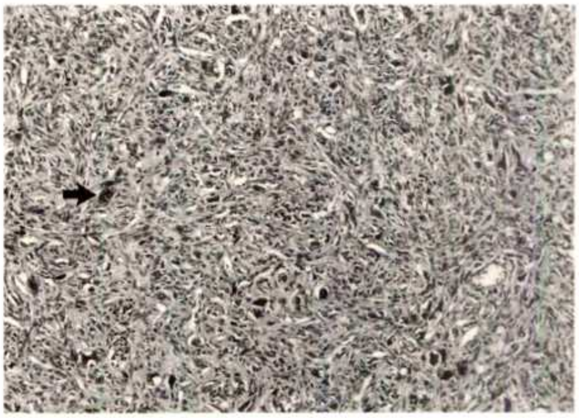

Figure 3. Low-power view showing pleomorphic tumour cells arranged in a storiform pattern. Tumour giant cells are arrowed.

Prognosis depends on local recurrence and haematogenous metastases, which are found primarily in the lungs (Dunham & Wilbourn, 1979; Yuen & Saw, 1985) and less commonly in the liver or other bones. Lymph node metastases are rare (Dunham & Wilbourn, 1979; Freyschmidt et al, 1981; Nakashima et al, 1985; Yuen & Saw, 1985). Five-year survival rate after resection of MFH is 30–50% (Huvos, 1976; Dahlin et al, 1977; Feldman & Lattes, 1977; Freyschmidt et al, 1981).

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Computed tomographic staging of testicular tumours: an unexpected source of error

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Computed tomography (CT) is widely used in the staging and follow-up of testicular tumours. Errors of interpretation may arise because of unopacified loops of bowel or aberrant vascular structures, but attention to technique, the use of an intravenous contrast agent and awareness of these potential pitfalls should prevent confusion with intra-abdominal tumour spread in these cases.

We describe a case in which a retroperitoneal haematoma following orchiectomy closely mimicked an iliac lymph node secondary deposit. Such an appearance may result in erroneous staging of testicular tumours and lead to inappropriate treatment.

Case report

A 28-year-old man, who complained of scrotal swelling, underwent surgical exploration of the scrotum via an inguinal incision and, on finding a testicular mass, a left orchiectomy was performed with removal of the extraperitoneal spermatic cord. Surgery and subsequent recovery were uncomplicated. Histology of the excised testicle showed the presence of a tumour confined to the testis with features typical of a pure seminoma. The urinary human chorionic gonadotrophin (HCG) and serum alpha-fetoprotein (AFP) were normal, confirming the absence of other germ-cell elements within the tumour. There was no clinical evidence of tumour spread. He was referred to a specialist oncology centre for tumour staging and 1 month after surgery underwent a computed tomographic (CT) scan of the chest, abdomen and pelvis.

The scan revealed the presence of a mass, 4 cm in diameter, within the pelvis (Fig. 1). It consisted of a thin, smooth rim and a homogeneous, low-attenuation (30 HU) centre. Posteriorly, the rim appeared to blend with the substance of the left psoas

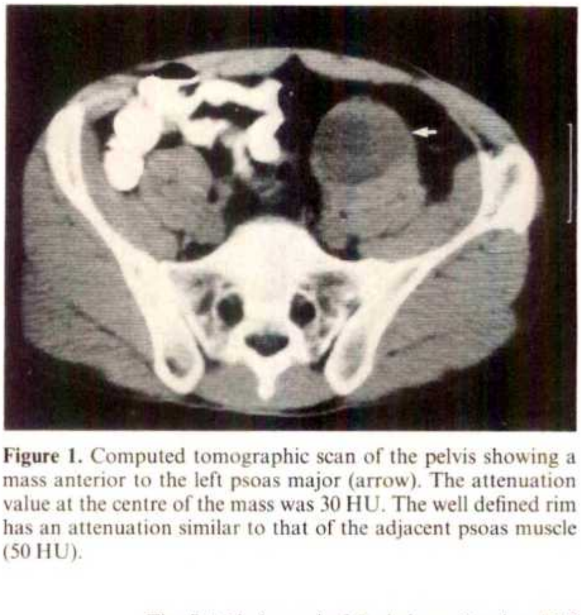

Figure 1. Computed tomographic scan of the pelvis showing a mass anterior to the left psoas major (arrow). The attenuation value at the centre of the mass was 30 HU. The well defined rim has an attenuation similar to that of the adjacent psoas muscle (50 HU).

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muscle, which was flattened by the mass. The anterior surface of the mass was smooth and well defined. No other masses or lymphadenopathy were present in the chest, abdomen or pelvis. Because of the absence of other involved nodes and because the site of the mass was unusual for a malignant lymph node deposit from a testicular tumour, a lymphocoele, secondary to surgery, was suggested. A lymphangiogram was performed, which showed no abnormality of the lymphatic vessels or nodes. A further CT scan after the lymphangiogram showed that the mass lay lateral and anterior to the left iliac nodes but did not communicate with the lymphatic system. An aspiration biopsy of the mass yielded altered blood only with no evidence of malignancy on cytological examination. A diagnosis of retroperitoneal haematoma was made. The patient required no further treatment. He has been followed-up for 2 years and remains tumour free.

Discussion

The lymphatic drainage of the testes reflects their embryonic intra-abdominal development and the normal pattern is into four to eight collecting trunks, which ascend in the spermatic cord and accompany the testicular vessels as they lie on psoas major; these lymphatics terminate in the lateral aortic and pre-aortic nodes (Williams & Warwick, 1980). Testicular tumours, especially seminomas, tend to metastasize via draining lymphatics and deposits are most frequently found in the para-aortic, mediastinal and renal hilar nodes. However, inguinal and scrotal surgery may disrupt the normal pattern of lymph drainage from the testicle (Busch et al, 1965) and, in addition, it has been suggested that the medial part of the testicle and epididymis may normally drain to the external iliac nodes (Fuchs, 1969). As a result, metastases to the iliac nodes may occur in testicular neoplasm.

The role of CT in the staging of testicular tumours is well established (Husband et al, 1979). Limitations of CT in the assessment of nodal deposits are well known and include the presence of deposits too small to be detected by CT and enlargement of nodes due to reactive hyperplasia, which cannot easily be distinguished from tumour involvement. In addition, errors may arise from the misinterpretation of unopacified loops of bowel or aberrant vascular structures as nodal masses. Despite these shortcomings, CT is the primary and often sole method of tumour staging in most patients, with lymphography reserved for selected cases. This is partly due to the relative ease and speed of CT scanning but also, more importantly, because of the ability to assess nodes in the upper retroperitoneum that cannot be adequately assessed solely by lymphography.

The appearance on CT of nodal metastases from malignant testicular tumours is variable and may be related both to tumour type and tumour necrosis. Necrosis may occur either spontaneously or after treatment. Scatarige and his co-workers (1983) found that nodal metastases had an attenuation value of less than 30 HU in 43.5% of cases, a figure similar to that of other workers (Husband et al, 1979). These low-attenuation deposits occurred in seminomas, mixed germ-cell tumours and embryonal tumours and were usually, but not always, associated with tumour necrosis. Where necrosis was not a feature, the finding occurred in a cystic teratomatous deposit.

It is accepted surgical practice to delay complex investigation, except for the collection of blood for tumour markers, until after surgery in suspected testicular neoplasms (Weinerth, 1986). The surgical approach is via an inguinal incision with clamping of the cord at the internal inguinal ring before manipulation and biopsy of the testicle. If orchiectomy is undertaken, the cord and its coverings are divided at the internal inguinal ring. This may lead to difficulty in achieving haemostasis as the cut vessels retract and may continue bleeding into the retroperitoneum.

The appearances on CT of a case of iliac haematoma after orchiectomy were reported by Kullmann and Lien (1987). The haematoma was observed after a similar post-operative interval and was in a similar position to the case we describe. However, the CT appearances were different, with low-attenuation values at the periphery and higher values at the centre. This appearance was considered useful in distinguishing these haematomas from low-attenuation deposits, which generally have a lower-attenuation centre resulting from necrosis. The case presented here shows that this is an unreliable sign, presumably because the appearance of the haematoma may change with the age and composition of its contents.

The consequences of a mistaken diagnosis of a lymph node deposit may be grave for the patient, as he may be subjected to unnecessary radiotherapy, chemotherapy, surgery or a combination of these depending on the tumour type and local treatment protocols. Scanning prior to surgery would avoid the problem but would result in delay in achieving a histological diagnosis and unnecessary scanning in those patients who, as a result of surgical exploration and biopsy, are found not to have malignant testicular disease. An appreciation of the possible post-orchiectomy appearance, lymphography in selected cases and aspiration biopsy remain necessary for correct interpretation whenever a mass is discovered at this location.

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Retroperitoneal mass and spinal cord compression due to extramedullary haemopoiesis in polycythaemia rubra vera

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The development of discrete masses of extramedullary haemopoietic tissue is well recognized in a number of diseases (Ward & Block, 1971); however, it has been described only rarely in the proliferative phase of polycythaemia rubra vera (Rice et al, 1980; Robitaille et al, 1985). Most cases of extramedullary haemopoiesis present with posterior mediastinal or extradural masses (Ward & Block, 1971) and spinal cord compression is also well documented with over 30 cases in the world literature (Cromwell & Kerber, 1978; Ligumski et al, 1978; Mann et al, 1987). The diagnosis of extradural extramedullary haemopoiesis is important since it responds well to radiotherapy (Sorsdahl et al, 1964; Cromwell & Kerber, 1978) and can otherwise lead to serious neurological sequelae or death.

We describe the radiological findings in a patient with retroperitoneal and extradural extramedullary haemopoiesis consequent on proliferative polycythaemia rubra vera. To our knowledge this is the first description of spinal cord compression by extramedullary haemopoiesis in uncomplicated polycythaemia rubra vera. This is also the first description of the radiological appearances of extramedullary haemopoiesis occurring in the retroperitoneal musculature. Despite the unusual aspects of this case, the radiological findings show significant similarities to extramedullary haemopoiesis occurring in more typical sites. These findings underline the salient features that should suggest the diagnosis of extramedullary haemopoiesis even if masses are found in uncommon sites.

Case report

A 52-year-old man presented with a 5-month history of low back pain radiating to the right thigh. Eight years previously he had suffered traumatic amputation of the right leg at mid femur. During the 2 months prior to admission, he had been unable to tolerate a prosthetic limb because of a tender swelling of the right buttock.

Clinical examination confirmed a tender swelling of the right buttock and paraspinal muscles; there was also marked facial plethora.

Laboratory investigations revealed polycythaemia (haemoglobin (Hb) 20.1 g/dl, packed cell volume (PCV) 0.65, mean corpuscular volume 73 fl, white blood cells 17.5×10^9/l, platelets 185×10^9/l). Red cell volume (53.1 ml/kg; normal 25–35 ml/kg) and plasma volume (54.6 ml/kg; normal 40–50 ml/kg) were both markedly elevated. Bone marrow aspiration demonstrated

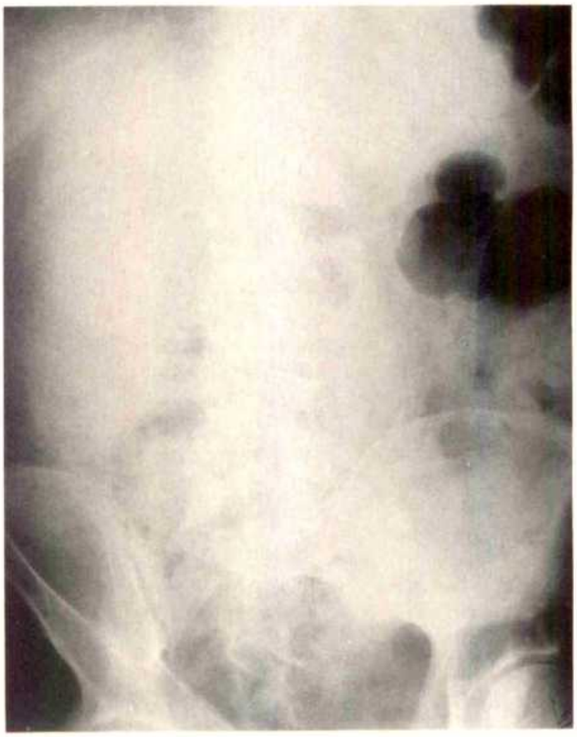
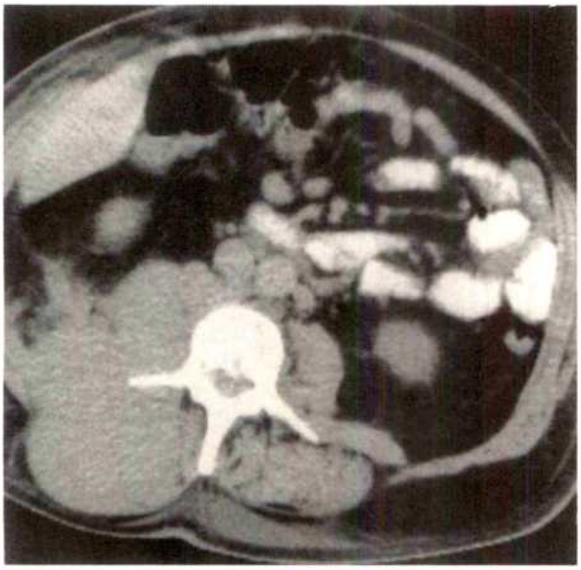
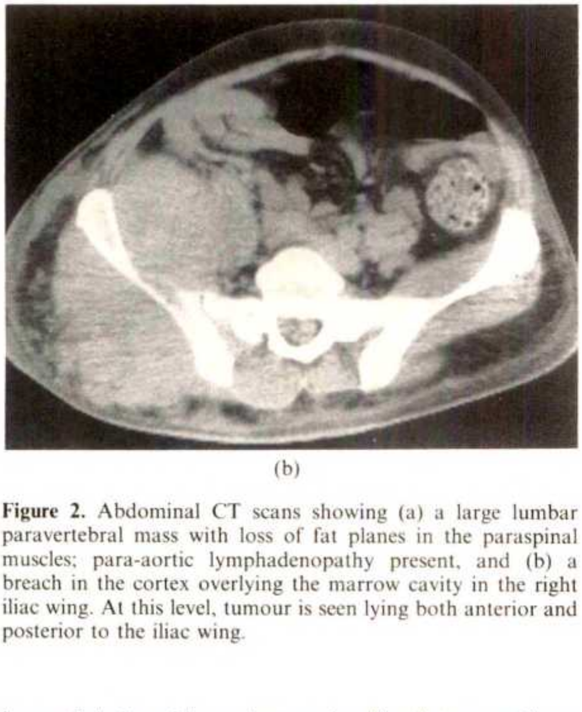


Figure 1. Abdominal radiograph showing destruction of the right sacral ala and deviation of the right psoas outline.

Address correspondence to Dr I. E. Burton.



(a)



(b)

Figure 2. Abdominal CT scans showing (a) a large lumbar paravertebral mass with loss of fat planes in the paraspinal muscles; para-aortic lymphadenopathy present, and (b) a breach in the cortex overlying the marrow cavity in the right iliac wing. At this level, tumour is seen lying both anterior and posterior to the iliac wing.

hypercellularity with an increase in all cell types with no increase in reticulin. A diagnosis was made of polycythaemia rubra vera in its proliferative phase. The patient was treated by venesection of 2 units of blood together with administration of ^{32}P (300 MBq). There was a slight fall in blood counts over the following 2 weeks (Hb 16.6 g/dl, PCV 0.51).

Radiographs of the chest and cervical and thoracic spine were normal. A radiograph of the abdomen (Fig. 1) demonstrated a right-sided, paraspinal, soft-tissue mass causing marked bulging and lateral displacement of the psoas outline. There was bone destruction at the upper border of the right sacral ala but no other bony abnormality was seen.

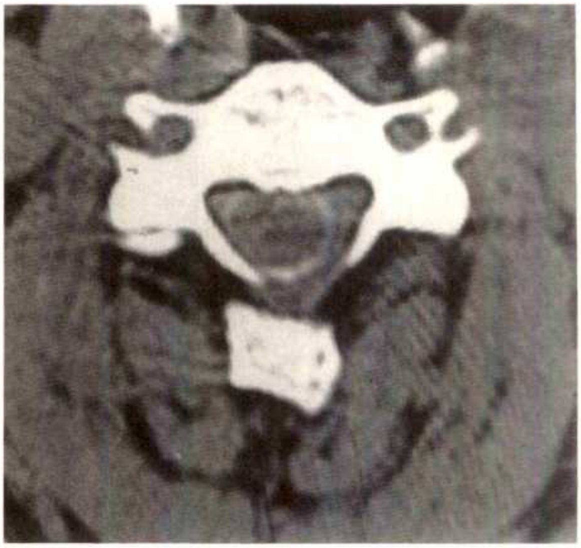


Figure 3. A CT myelogram at the level of the fourth cervical vertebra showing an extradural, soft-tissue tumour. A complete block was present at the section level immediately below this.

A computed tomographic (CT) examination of the abdomen and pelvis (Fig. 2) demonstrated enlargement of the spleen. In addition, cortical defects were noted in the ventral surface of the right iliac wing and in the right sacral ala, communicating with the underlying marrow cavity. There was enlargement of the iliopsoas muscle overlying the sacral defect with loss of delineation of the muscle planes between the iliopsoas and quadratus lumborum. The retroperitoneal muscles were expanded forming a large retroperitoneal soft-tissue mass that extended anteriorly, apparently encasing the inferior vena cava and reaching the aorta; a number of enlarged para-aortic lymph nodes were noted. The mass was continuous over the superior aspect of the right sacral ala with the gluteal muscles and extended into the right buttock. The mass was homogeneous, of soft-tissue density and calcification was not present. Despite the extensive paravertebral extension of the mass there was no bony abnormality other than that described above.

Trucut needle biopsy revealed typical appearances of extramedullary haemopoiesis with myeloid, erythroid and megakaryocytic lines all present.

Two weeks after treatment, the patient developed a rapidly progressive quadriplegia with an upper thoracic sensory level. Computed tomographic myelography demonstrated a complete block resulting from an extradural, soft-tissue tumour at the level of the fourth cervical vertebra (Fig. 3). There was no evidence of bony abnormality. Despite local radiotherapy (1500 Gy, single fraction), the patient died shortly afterwards from respiratory failure.

Post-mortem examination confirmed cervical spinal cord compression due to a 10 cm long mass of extramedullary haemopoiesis extending down from the level of C4. There was hepatosplenomegaly (liver 2596 g, spleen 554 g) with foci of extramedullary haemopoiesis throughout both organs. A large, right-sided, retroperitoneal mass of extramedullary haemopoiesis was also confirmed. Affected tissues were firmly adherent to each other and there was encasement and compression of the

Table I. Reported causes of extramedullary haemopoiesis

	Common causes	Rare causes
Increased red cell destruction	Thalassaemia[a] Hereditary spherocytosis[a] Erythroblastosis fetalis[a]	Haemorrhagic disorders Pyruvate kinase deficiency[a]
Inefficient haemopoiesis		Pernicious anaemia Septicaemia Bone marrow transplant Rickets Hepatic failure
Marrow infiltration	Myelofibrosis[a]	Lymphoma Leukaemia Carcinomatosis
Myeloproliferative disorders	Agnogenic myeloid metaplasia[a]	Polycythaemia rubra vera[a]

[a]Indicates disorders that have been associated with tumoral masses of extramedullary haemopoiesis.

inferior vena cava. Encasement of the abdominal and lower thoracic aorta was also found, which had not been noted on CT.

Discussion

Extramedullary haemopoiesis is a well recognized complication of diseases in which there is encroachment on marrow spaces or a chronic increase in the rate of production of red cells (Danza et al, 1982). It is most commonly associated with congenital haemolytic anaemias but has been described in many other disorders (Lowman et al, 1963; Ross & Logan, 1969; Ward & Block, 1971; Table I). Myelofibrosis, either primary or as a sequela of polycythaemia rubra vera, is one of the commoner causes of extramedullary haemopoiesis; however, the case described here is only the third associated with the proliferative phase of polycythaemia (Rice et al, 1980; Robitaille et al, 1985).

Extramedullary haemopoiesis invariably involves the liver and spleen and lymph node involvement is also common. Splenomegaly is usually seen and is often associated with hepatomegaly. In addition, multiple nodules of extramedullary haemopoiesis have been described in the adrenal gland, kidney, thymus, dura, breast, epididymis, peripheral nerve, cartilage, adipose tissue and organizing thrombi (Lowman et al, 1963; Sorsdahl et al, 1964; Shaver & Clore, 1981). These multiple disseminated lesions are usually small and have no significant mass effect, commonly presenting as incidental findings at post-mortem examination. Far more unusual is the production of large tumours of extramedullary haemopoiesis, which are most commonly seen in the thorax (Long et al, 1980) and extradural space (Cromwell & Kerber, 1978), and have been rarely described in adrenal, kidney and retroperitoneum (Ward & Block, 1971; Danza et al, 1982; King et al, 1987). Large masses of extramedullary haemopoiesis can be life-threatening as in the current case and often cause serious diagnostic difficulty.

Thoracic masses of extramedullary haemopoiesis are most commonly described in patients with thalassaemia or hereditary spherocytosis, especially in those who have not undergone regular transfusions (Faloppa et al, 1981). The plain radiographic appearances of such mediastinal masses are well documented (Lowman et al, 1963; Sorsdahl et al, 1964; Ross & Logan, 1969; Faloppa et al, 1981). They present as well demarcated, round or lobulated masses usually in the posterior mediastinum below the level of T6. They may be unilateral or bilateral, do not contain calcification and are not associated with bone destruction. Skeletal changes of chronic anaemia or myelofibrosis may be present. Computed tomographic studies of extramedullary haemopoiesis (Long et al, 1980; Faloppa et al, 1981; Danza et al, 1982) have described homogeneous, well demarcated, soft-tissue masses usually in the paravertebral region confirming the absence of calcification and bone destruction. Mediastinal and abdominal para-aortic nodes may be enlarged but hilar adenopathy is rare. Discrete, subpleural masses have been described adjacent to ribs, which may show expansion of the marrow cavity with endosteal cortical thinning or complete cortical breaks. Masses of extramedullary haemopoiesis have been detected on CT in the absence of plain radiographic abnormality.

In the current case, extramedullary haemopoiesis also presented as a well defined, paravertebral, soft-tissue mass without calcification. Local adenopathy was present and bone destruction was seen, allowing continuity between the mass and a marrow cavity similar to that described in rib lesions. It can be seen that the radiological features are consistent with those described for thoracic tumours, although the encasement of great vessels seen here has not been described in the thorax. The CT findings of an extradural, soft-tissue mass causing spinal cord compression without bone destruction are similar to those reported by previous workers.

It has been suggested that extramedullary haemopoiesis occurs following deposition of circulating, pluripotent stem cells from the bloodstream, by venous embolism from the bone marrow (Ask-Upmark, 1945) or by extrusion of marrow through bony cortical defects (Ross & Logan, 1969). The CT findings of Long et al (1980) and those in the current case support the extrusion theory by demonstrating continuity between the tumour and the marrow cavity.

Many cases still result in death because of late diagnosis. There are several reports of good therapeutic response to radiotherapy or surgical debulking (Crawford et al, 1984), especially if combined with blood transfusion (Mann et al, 1987), and a high degree of clinical suspicion is therefore warranted.

The diagnosis is suggested by a combination of the following features.

1. Large, intrathoracic, extradural or retroperitoneal soft-tissue mass without calcification or bone destruction.
2. Endosteal cortical thinning in association with a soft-tissue mass, especially if continuity between the mass and the marrow cavity is demonstrated.
3. History of chronic anaemia, myelofibrosis or myeloproliferative disorder.
4. Splenomegaly or history of splenectomy for haematological disease.

Extramedullary haemopoiesis may also be detected by radionuclide imaging with ^{99}Tc^{m} sulphur colloid or ^{111}In chloride. Whatever radiological technique is used to demonstrate disease, biopsy confirmation is essential.

Acknowledgments

The authors would like to thank Dr G. Hartley for permission to report the radiological findings in this case.

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Computed tomography of earpits-deafness syndrome

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(*Received December 1988*)

Earpits-deafness syndrome is a congenital syndrome in which branchial arch anomalies are associated with hearing loss. The inheritance is autosomal dominant, and the anomalies consist of any or all of the following: auricular deformities, pre-auricular pits or sinuses, branchial fistulae or cysts, external auditory meatus atresia and conductive or mixed hearing loss. Renal anomalies have also been described in association with the syndrome (Melnick et al, 1976; Cremers & van Noord, 1980).

Case report

We describe the appearances on computed tomography (CT) in one family with four generations known to be affected with

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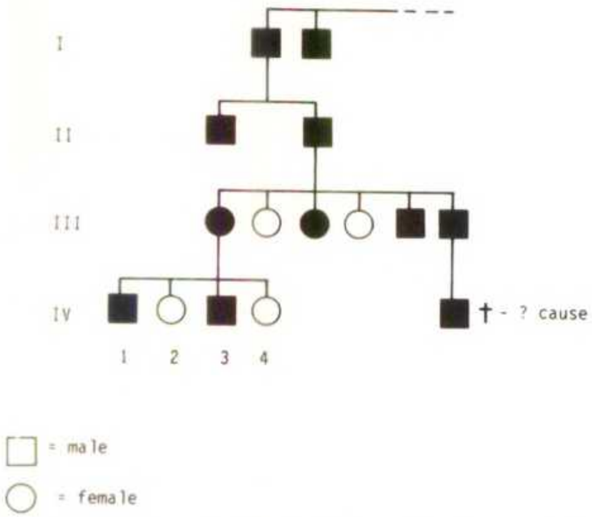

Figure 1. All affected members of the family (shaded) with mixed hearing loss and pre-auricular sinuses and branchial fistulae.

the syndrome. The family pedigree is shown in Fig. 1. The proband (IV_3) presented at the age of 3 years with a mixed sensorineural and conductive hearing loss. He was referred for myringotomy and found to have dry ears but was noted to have pre-auricular sinuses and branchial fistulae. His brother, 4 years older, had a conductive hearing loss, and his mother had mixed hearing loss. They both also had pre-auricular sinuses and branchial fistulae. Impedance studies in all three cases were normal, suggesting the absence of ossicular fixation. None of the affected members of the family had renal symptoms and were therefore not investigated for renal anomalies.

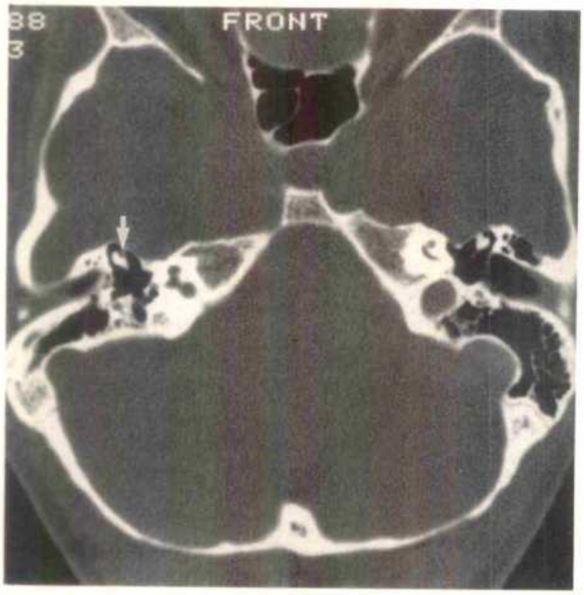

Figure 2. Axial CT section of the mother showing malrotation of the petrous temporal bones with anteriorly situated hypoplastic ossicles (arrow) and small cochleae.

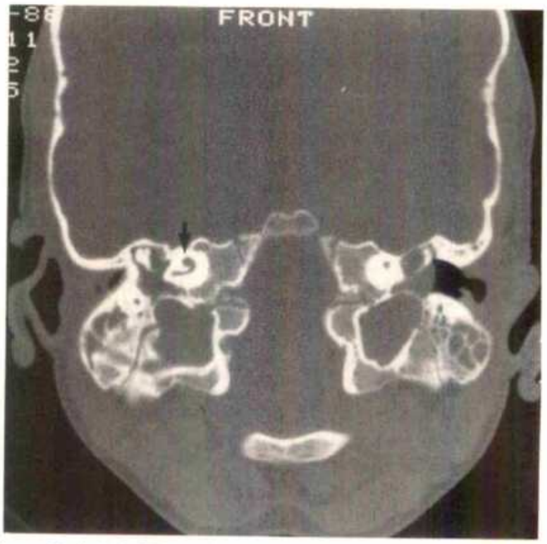

Figure 3. Axial CT section of petrous temporal bones of the younger son (IV_3). These appearances are similar to the mother's, but with opaque middle ears, presumably due to serous otitis media. Note the small cochlea (arrow) with reduced number of turns.

Coronal and axial CT scans were performed in the brother and mother (Fig. 2). Axial scans only were performed in the proband (Fig. 3), who was rather young to co-operate fully; 1 mm contiguous slices were taken, with a kV of 125 and an mAs of 550. In the mother and brother, there was upward tilt of the medial end of the petrous temporal bone with large jugular fossae. The incus appeared to be hypoplastic. All three patients were found to have rather small cochleae, with a reduced number of turns in the mother and proband.

Discussion

The radiological findings in seven patients with the earpits-deafness syndrome have been described by Slack and Phelps (1985). Characteristic features include abnormal ossicles, a smaller than normal cochlea with a reduced number of turns, but without a definite distal sac, a short, wide internal auditory canal, which may be related to malrotation of the petrous pyramid, and a short upward-pointing lateral semicircular canal. These findings have been confirmed in this family.

The exact mechanism of the conductive hearing loss in these patients is not well understood. It may be due to ossicular fixation in that the footplate of the stapes may be fixed in the oval window, or the malleus and incus may be immobilized in some cases by bony adhesions within the attic. Reconstructive surgery would be difficult if there is not good access to the oval window. In any case, surgery would only be of value in the presence of a significant air–bone gap (>40 dB). Neither the proband nor his mother had an air–bone gap >40 dB (Fig. 4). The value of CT in patients with a

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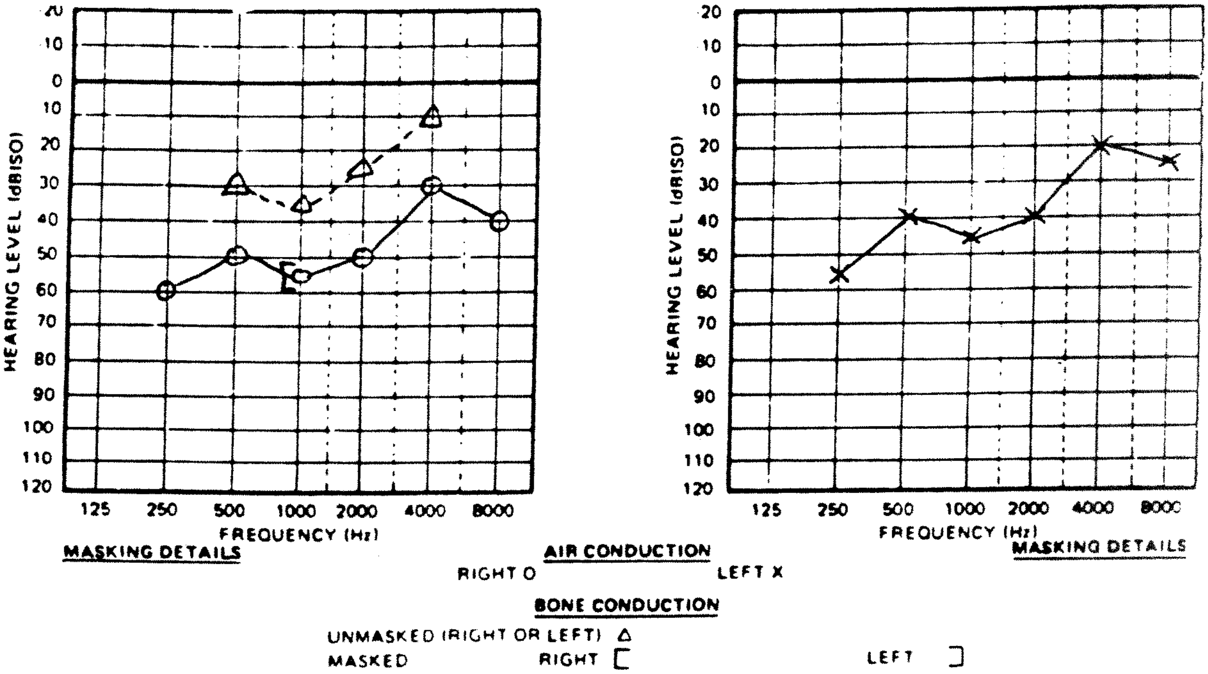

Figure 4. Audiogram of the mother showing mixed hearing loss.

significant air–bone gap would be mostly to determine the position and size of the oval window, and hence operability.

It is important to recognize these patients for the purposes of genetic counselling, and also for the detection and appropriate management of hearing loss at an early age in affected members of the family. All children presenting with branchial arch problems should undergo hearing tests.

Acknowledgments

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Acute toxic myopathy: a delayed adverse effect of intravenous urography with iopamidol 370

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We report the case of a patient who developed severe muscle pains due to acute toxic myopathy following intravenous urography. This is a previously unreported adverse reaction to intravenous contrast media and occurred with iopamidol 370, a low-osmolar, non-ionic agent.

Case report

A 55-year-old man was referred for intravenous urography (IVU) during investigation for poorly controlled hypertension. His only medication was atenolol (50 mg *mane*) and slow-release nifedipine (20 mg bi-daily); there was no other past medical history of note. A bolus of 50 ml of iopamidol (Niopam 370, Bracco) was injected into an antecubital vein. No extravasation was noticed and there were no immediate side-effects. An hour later, he developed severe pains in both upper arms, which gradually worsened, and 5 h after the IVU he was admitted to hospital.

On admission he had an axillary temperature of 39°C and the muscles of both upper arms were acutely tender. No other abnormalities were detected on examination. Full blood count, erythrocyte sedimentation rate, blood cultures, urine microscopy and culture, chest radiography and electrocardiography were all normal. On admission, the serum urea and electrolytes were normal apart from a potassium of 3.1 mmol/l (normal range 3.5–5.3 mmol/l). Serum creatinine phosphokinase (CPK) taken 12 h after admission was markedly elevated at 835 i.u./l (normal range 25–95 i.u./l), the serum lactate dehydrogenase level was also raised at 1112 i.u./l (normal range 230–460 i.u./l), but unfortunately the urinary myoglobin was not measured. In the 36 h following admission, the serum urea rose to a maximum of 21.3 mmol/l (normal range 1.0–6.5 mmol/l) and the serum creatinine to a maximum of 319 μmol/l (normal range 60–120 μmol/l) although his urine output remained normal. Over the next 3 days, the muscle pains abated, the temperature settled and the urea and creatinine returned to normal. He was discharged home and on follow-up 2 months later he was well although still hypertensive.

Discussion

The onset of severe muscle pain associated with a raised CPK level and followed by a temporary elevation of serum urea and creatinine indicates that the injection of iopamidol 370 had induced muscle necrosis with myoglobinuria (Argon & Mastaglia, 1988) (even though myoglobinuria was not actually documented in this case). A number of drugs are capable of causing an acute necrotizing myopathy with myoglobinuria (Argon & Mastaglia, 1988) but we have been unable to find a previous report of this as an adverse reaction to intravenous contrast media. Myoglobinuria has been reported following myelography with meglumine iothalamate (Conray, May & Baker) (Nielsen & Nielsen, 1974) but this was thought to be due to uncontrolled muscle spasms rather than a contrast medium reaction. Mozley (1981) described a case of malignant hyperthermia following intravenous iodinated contrast medium, although the medium used was not stated. This case was characterized by the onset of leg pains 3 min after the injection followed by muscle spasm, hyperpyrexia, tachycardia and acidosis. Death occurred 6½ h after the injection. Fatal vasculitis following urography has been reported in two patients with systemic lupus erythematosus (Goodfellow et al, 1986; Savill et al, 1988) and Kerdel et al (1984) described two other cases of cutaneous necrotizing vasculitis from radiographic contrast media.

Delayed arm pain has been reported in 13% of patients following intravenous urography and in 65% of these the pain was above the site of the injection. However, in these cases, the pain was limited to the site of injection and is thought to be due to a direct toxic effect of the contrast medium on the vascular endothelium (Panto & Davies, 1986).

Acknowledgments

We would like to thank Dr W. J. Jeffcoate for allowing us to publish details of this case.

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Case of the month

Radio-opaque hemithorax in a neonate

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A 1-day-old male infant, delivered by Caesarean section at term to a 20-year-old primigravida, presented with an apnoeic episode associated with hypoxia and cyanosis. The chest radiograph at presentation showed an opaque right hemithorax (Fig. 1). Treatment with antibiotics and oxygen was commenced, and the baby gradually improved over the subsequent 10 days. A repeat chest radiograph was unchanged in appearance. An ultrasound examination of the liver (Fig. 2) and a perfusion scan of the chest (Fig. 3) were performed.

What abnormalities have been shown and what is your differential diagnosis?

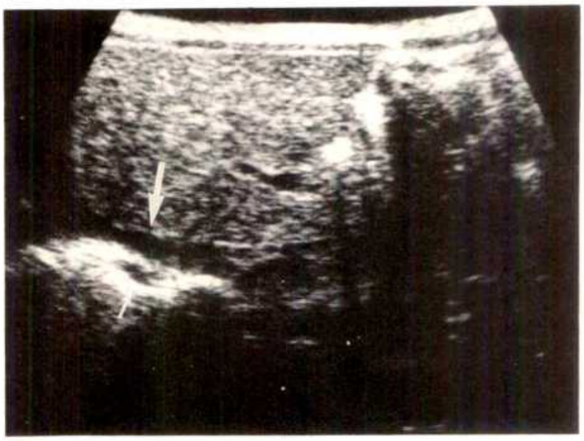

Figure 2. Longitudinal section through the liver. Small arrow, anomalous vessel; large arrow, inferior vena cava.

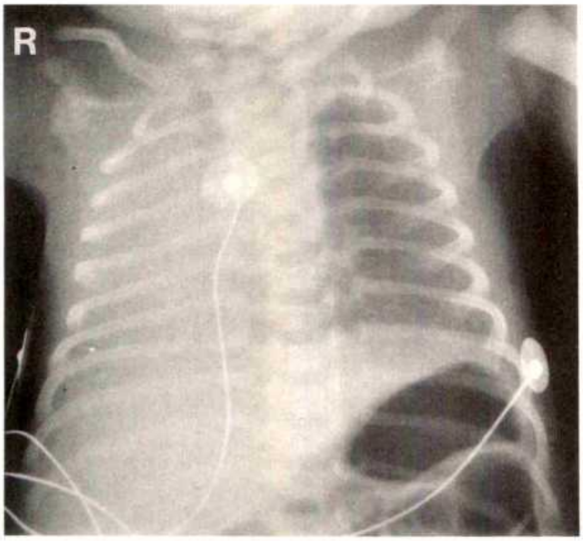

Figure 1. Chest radiograph at Day 1 showing an opaque right hemithorax.

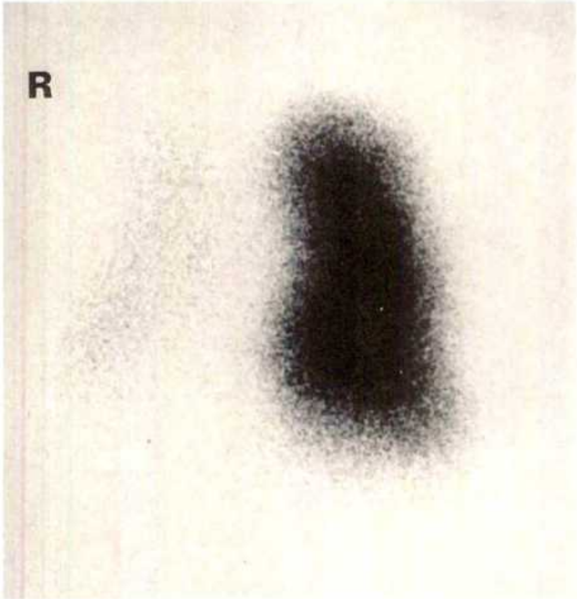

Figure 3. ^{99}Tc^{m}-microsphere perfusion scan.

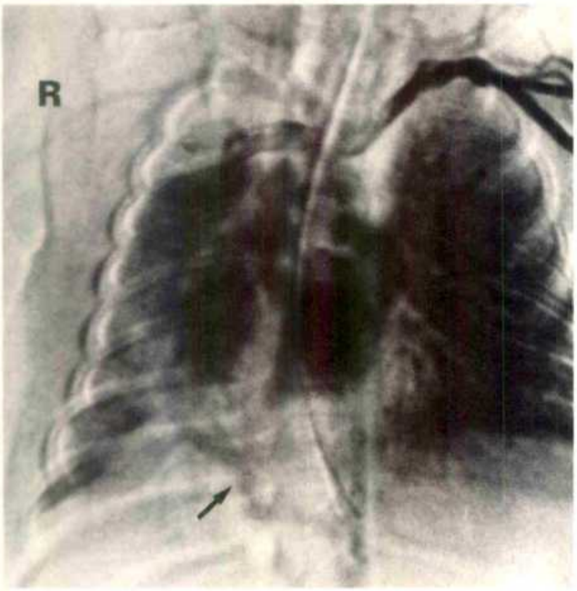

Figure 4. Late DSA image showing the anomalous artery (small arrow) arising from the abdominal aorta and passing obliquely above the right hemidiaphragm.

The differential diagnosis includes collapse/consolidation of the right lung secondary to infection, obstruction of major bronchi by mucus plugs or aspiration of meconium or fluid. Congenital abnormalities such as complete lobar agenesis and pulmonary sequestration, although rare, are definite possibilities. If there was less evidence of mediastinal shift, the differential diagnosis would be enlarged to include causes of pleural fluid collections. Thus, hydrothorax, pyothorax, haemothorax and chylothorax (commoner in males and on the right side) would be considered.

In our patient, the initial ultrasound examination revealed an aberrant vessel passing obliquely from the region of the aorta, behind the inferior vena cava and traversing the right hemidiaphragm. A ^{99}Tc^{m}-microsphere perfusion scan showed hypoperfusion of the right lung via the pulmonary circulation. The definitive diagnosis was made by an intravenous digital subtraction angiogram (DSA) (Fig. 4), using a peripheral injection incorporating the limb muscle compression technique (Lea Thomas & Hicks, 1987). With this technique, contrast medium is injected into a superficial hand or foot vein and is held in the deep venous system by application of tourniquets. By simultaneous release of tourniquets and limb compression, a satisfactory bolus of contrast medium can then be propelled into the central veins. The intravenous DSA study shows an anomalous artery arising from the abdominal aorta and passing above the right hemidiaphragm.

The diagnosis in this case was pulmonary sequestration. It is of interest that the diagnosis was reached in a relatively non-invasive manner using imaging facilities commonly available within a District General Hospital.

Pulmonary sequestration is part of the broad spectrum of congenital bronchopulmonary-vascular malformations. The term was first used to describe a "disconnected bronchopulmonary mass or cyst with an anomalous systemic artery supply" (Pryce, 1946). Subsequently, cases were discovered that did not correspond to the original description and hence the term "sequestration spectrum" was coined (Sade et al, 1974). More recently, Clements and Warner (1987) have attempted to apply a unifying concept to all congenital lung lesions on the basis of abnormal development of the four principal lung constituents, namely tracheobronchial airway, lung parenchyma, arterial supply and venous drainage. Their scheme provides a theoretical explanation as to how a single insult, occurring during early lung development *in utero*, can produce such diverse congenital abnormalities as pulmonary sequestration, the "scimitar" syndrome, cystic adenomatoid malformation and congenital lobar emphysema.

Our patient had a right-sided pulmonary sequestration and underwent embolization of the anomalous vessel. At the present time he remains well.

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Correspondence

(The Editors do not hold themselves responsible for opinions expressed by correspondents)

The influence of tube type and operator experience on performance of small bowel enema

THE EDITOR—SIR,

I read with interest the paper of Nicholson et al (1989) regarding the influence of tube type and operator experience on the performance of small bowel enemas. However, I was surprised that the paper gave scant description of the intubation technique and made no mention of the different techniques used by different operators. Am I to assume that all the radiologists involved used the same technique? If this were so, a description of the technique would be helpful.

I perform small bowel enemas on adults and children and use the same technique for intubation (a modification of the technique for the passage of a Crosby capsule in children) regardless of the patient's age. A child will tolerate only one attempt at small bowel intubation and thus an exacting routine is necessary. The tube is passed through the nose or mouth, depending on the patient's preference, with the patient lying supine. As soon as the tube enters the stomach the patient is turned onto the right side and then forward into the semi-prone position. The stomach is then inflated with 75–150 ml of air and the guidewire is inserted into the tube to prevent the air escaping. The tube is then advanced through the stomach with the heavy-duty guide advanced to within 7 cm of the tip of the tube. With the patient in the right-side down, semi-prone position, the tube advances into the pylorus carried through the distended body of the stomach by the weight of the guide. This prevents the tube entering the gastric fundus, which frequently occurs if the tube is passed with the patient supine or in the semi-erect position. To pass the tube into the pylorus in such a manner takes only 30 s and requires very little fluoroscopy. At this point the patient is turned back to a semi-supine position to facilitate fluoroscopy. The tube and guide are advanced together into the duodenal cap. As the tip of the tube enters the duodenum it points upwards and then tips backwards. If the tube turns medially towards the spine it is curling up in the pylorus. If there is any delay in the passage of the tube from pylorus to duodenum the patient is immediately placed in the right-side down position and 10 ml of 100% barium is injected. The patient remains in the right-side down position with no further tube manipulation until the barium has demonstrated the anatomy of the pylorus and duodenum. The patient is then returned to a right-side down, semi-supine position and the barium coating the pylorus and duodenum is used as a guide for further tube manipulation. Once the tube has entered the duodenum it is advanced over the guidewire until well into the jejunum.

Using this technique the majority of tubes are passed in 2 min or less. If the tube has not entered the jejunum within 5 min of the start of the procedure but has reached the duodenal cap or beyond, barium is infused with the tube in this position. In the small number of children in which infusion has been undertaken in this way, satisfactory examinations have been achieved without vomiting albeit with some gastric reflux. This necessitates the patient being semi-erect and the right side raised 30° to ensure that the infused barium passes through the duodenum and not back into the stomach.

In this technique, intubation times are far shorter than those described by Nicholson et al and screening times are also considerably shorter. Although only one patient in the series was a child, I consider the screening times for both intubation and examination to be too long for adults or children, and fluoroscopy must account for a considerable part of the procedure's radiation dose. The even longer screening times of other authors quoted in this paper are astounding, considering that the small bowel enema is a routine procedure.

To achieve rapid small bowel intubation requires a firm tube. The Silk tube used in this study is very pliable and kinks easily, preventing rapid insertion. The Nolan tube is in my view rather too stiff but its guidewire is excellent. A good compromise is to use a Vygon naso-jejunal feeding tube, which is made of relatively soft plastic with a Nolan type guidewire. The Nolan type Bilbao-Dotter tube (Cook) is expensive, costing £34.96 including VAT. The Silk tube (Merck) costs £14.20 including VAT while the Vygon feeding tube costs only £0.77 including VAT and thus we can afford to use a new Vygon tube for each patient. The feeding tubes have the further advantage of being available in a range of sizes including 8, 12 and 14 French. The larger tubes have connectors of the type found on Foley catheters, which allow far higher flow rates than the narrow-bore connectors on Nolan and Silk tubes. The feeding tubes do have the disadvantage of having multiple side-holes through which the guidewire may pass, but this occurs only if the guide is advanced too close to the tube tip with the tube curved and it is easily recognized on fluoroscopy.

In conclusion, from my own experience of small bowel enemas, I am surprised that this paper has found so little difference in intubation times and intubation screening times between experienced and inexperienced radiologists. Perhaps this is due to a lack of a clear cut intubation technique that might be learned and improved on with experience. I suggest that a more careful study of intubation technique would considerably reduce intubation time and intubation screening time for what has become a routine form of examination in many departments.

Yours, etc.,
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(*Received May 1989*)

(*Authors' reply*)

THE EDITOR—SIR,

Dr Bisset makes a number of points to which we wish to respond.

(1) The intubation technique for small bowel enema used by the authors was substantially as described by Nolan and Cadman (1987). We find this an effective technique, which is easy for trainee registrars to learn. It is also simple for the patient, as it requires the minimum of twisting and turning on the unyielding fluoroscopy table, which can be particularly difficult for the elderly, the infirm and the asthenic. We agree with Dr Bissett that when the tube cannot be passed into the jejunum, it is useful to elevate the patient's right side in order to discourage duodeno-gastric reflux, although this manoeuvre slows the passage of barium into the ileum and it is generally necessary for the patient to resume the supine position for the

ileum to fill adequately. Our experience of insufflation of the stomach to ease passage of the tube is that this primarily distends the fundus and tends not to help.

(2) Dr Bissett is critical of the intubation times and fluoroscopy times reported in our paper. Our times are in broad agreement with those reported by others (Ott et al, 1985; Nolan & Cadman, 1987) and are an honest and accurate audit of our performance. Naturally, every effort is made to minimize radiation dose but it is recognized (Ott et al, 1985) that a higher radiation burden is the price paid for the small bowel enema compared with the barium follow-through. This inevitable fact is one of the considerations taken into account when selecting small bowel enema as a method of investigation. Dr Bissett's ability to intubate the jejunum in the majority of his patients in 2 min or less is enviable. I am sure that others would join us in encouraging him to undertake a prospective evaluation of his technique so that he too may report his own honest and accurate results.

(3) Both the Nolan and the Silk tubes are indeed relatively expensive but there is nothing to prevent either tube from being used repeatedly. The Nolan tube is of sturdy construction and a single tube can be used for many patients. Indeed, in our study, two Nolan tubes were used and these two tubes are still in use in the department. Thorough washing of the tube and guidewire in soap solution, followed by disinfection in Cidex (2% glutaraldehyde) for 10 min is adequate. The limitations of the Silk tube with regard to re-use are first that the spiral-wound guidewire is easily kinked and can then not be re-used, although guidewires can be purchased separately. Secondly, the tube is coated with a lubricant that is activated by wetting. This appears to be less effective with re-use, although in our study we found that each Silk tube could be used on approximately three patients.

The aim of our paper was to encourage the use of small bowel enema, where appropriate, by radiologists who are currently not keen to perform what they may consider a time-consuming investigation. We are encouraged by Dr Bissett's comments.

Yours, etc.,
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Ten-year results of a post-operative prospective trial: NSD and LQ correspondence

THE EDITOR–SIR,

In a recent issue of the *Journal*, Dr Bates (1988) reported on the 10-year results of a prospective trial involving 411 patients. From these results, certain conclusions were drawn on the assumption that the doses used produced equal effects based on clinical observations.

Three radiotherapy techniques were used and 12 fractions in 28 days were compared with six fractions in 18 days.

(1) The cervico-axillary chain of nodes was treated with ^{60}Co to a maximum tissue does of 51 Gy with 12 fractions, or 35 Gy with six fractions.
(2) The internal mammary chain was treated with a direct field using a half and half combination with ^{60}Co and ^{137}Cs. The maximum tissue dose was 52 Gy with 12 fractions, and 35 Gy with six fractions.
(3) The chest wall was treated with a direct field of 70 kVp X rays. The maximum tissue dose was 37 Gy with 12 fractions, and 31.5 Gy with six fractions.

The restriction of shoulder movement, lymphoedema of the arm and apical lung fibrosis were considered "late-effect" criteria under Technique 1; late skin changes on the chest wall were compared under Technique 3. No comparisons were useful in connection with Technique 2. The late effects are the important normal-tissue reactions and Dr Bates is to be congratulated on a meticulous 10-year follow-up.

The effects as recorded were not equal using Techniques 1 and 3. However, Dr Bates concluded that her results did not accord with the nominal standard dose (NSD) concept and calculated a negative value for the α/β ratio. This contribution is an analysis of the doses used in the different techniques by the NSD–time, dose, fractionation (TDF) and the linear-quadratic (LQ) models and shows that the results fit the NSD–TDF concept and the NSD formula (modified for late effects with large-fraction doses) as well as the LQ model.

The NSD formula (Ellis, 1967, 1968, 1969) was intended to apply to ^{60}Co radiation on connective tissue and to late effects, which were considered then by workers to be parallel to the acute effects of radiation. This view is no longer held because while the early effects were shown by Turesson and Notter (1975), when testing the NSD concept by clinical experiment, to fit the NSD formula, the late effects were found to require modification by multiplying the dose per fraction by a factor L_d, which increased progressively for fraction sizes >2 Gy, as shown in Table I.

At the time the concept was developed, it was recognized (Ellis, 1967) that NSD values could not logically be added. However, this was not stated as "partial tolerance" until 1969

Table I. Variation in correction factor (L_d) for equivalent late effects with dose per fraction (d) (derived from Turesson & Notter (1975))

d	L_d
2.0	1.0
2.5	1.01
3.0	1.02
3.5	1.03
4.0	1.04
4.5	1.05
5.0	1.06
5.5	1.07
6.0	1.08
6.5	1.09
7.0	1.1
7.5	1.12

(Ellis, 1969). Because "tolerance" relative to 1800 rets is frequently exceeded, the term "proportional tolerance" is preferred:

$$\text{Proportional tolerance (PT)} = \frac{n}{N}$$

where n is the number of fractions of the same dose d given with the same time-gap in days between fractions (T/n) as would require N fractions for 1800 rets.

$$\frac{n}{N} = \frac{\log S_n}{\log S_N} \text{ as } S = \mathrm{e}^{-n(\alpha d + \beta d^2)}$$

where S is survival (Winston et al, 1969).

1800 rets corresponds to a TDF of 100 (Orton & Ellis, 1973). Because

$$Nd = \mathrm{NSD} \times N^{0.24} \times T^{0.11}$$

it is clear that

$$Nd = \mathrm{NSD} \times N^{0.24} \times N^{0.11} \times \left(\frac{T}{N}\right)^{0.11}$$

and

$$N^{0.65} = \frac{\mathrm{NSD}}{d} \times \left(\frac{T}{N}\right)^{0.11}$$

i.e.

$$N = \left[\frac{\mathrm{NSD}}{d} \times \left(\frac{T}{N}\right)^{0.11}\right]^{1/0.65} = \left[\frac{\mathrm{NSD}}{d}\left(\frac{T}{N}\right)^{0.11}\right]^{1.54}$$

where T/N is the time-gap factor, *e.g.* 1.4 for five fractions in 7 days and 2.33 for three fractions in 7 days.

The late effects in all the areas treated in this prospective trial were those resulting in normal connective tissue to which the NSD concept applies. If

$$S = \mathrm{e}^{-(\alpha d + \beta d^2)N}$$

where N is the number of fractions of d Gy, then $\log S$ is proportional to N and for the same tissue, fraction dose and frequency of treatment the PT is

$$\frac{\log S_1}{\log S_2} = \frac{N_1}{N_2}$$

If n fractions are used when N fractions correspond to 1800 rets (100 TDF) then

$$\mathrm{PT} = \frac{n}{N} \quad \text{and TDF} = 100 \times \mathrm{PT}$$

The relationship of TDF to 1800 rets was described by Orton and Ellis (1973). The PT/TDF values in Techniques 1 and 3 as given by Dr Bates are as follows:

Technique 1a

For 51 Gy in 12 fractions in 28 days:

$$\frac{51}{12} = 4.25 \text{ Gy per fraction: } L_d \text{ factor} = 1.045$$

$$dL_d = 4.44 \text{ Gy.}$$

To obtain the proportional tolerance (PT) compared with tolerance for an NSD of 18 Gy (or PT × 100 = TDF):

$$N_{4.44} = \left[\frac{18}{4.44} \times \left(\frac{28}{12}\right)^{0.11}\right]^{1.54} = 9.94 \text{ fractions}$$

Thus:

$$\mathrm{PT} = \frac{12}{9.94} = 1.207 \text{ (\textit{i.e.} 121 TDF)}$$

Technique 1b

For 35 Gy in six fractions in 18 days:

$$\frac{35}{6} = 5.83 \text{ Gy per fraction; } L_d \text{ factor} = 1.077$$

$$dL_d = 6.28 \text{ Gy}$$

Thus, to obtain PT:

$$N_{6.28} = \left[\frac{18}{6.28} \times \left(\frac{18}{6}\right)^{0.11}\right]^{1.54} = 6.09 \text{ fractions}$$

$$\mathrm{PT} = \frac{6}{6.09} = 0.99. \text{ (\textit{i.e.} 99 TDF)}$$

Thus, according to the NSD concept, the late effects of 12 fractions of 4.25 Gy in 28 days should be greater than those of six fractions of 5.83 Gy in 18 days on the connective tissues treated in the axillo-cervix region, as was shown by Dr Bates' results.

Using Technique 3, the chest wall was treated with 70 kVp radiation and the maximum dose was deposited to the skin. Two corrections must be applied. The first is a relative biological effectiveness (RBE) factor. By clinical observation the dose to be used in the NSD formula should be divided by an RBE factor of 0.8 for this radiation since the NSD formula applies to ^{60}Co radiation. The late-effect factor should then be applied to estimate the PT for present purposes.

Technique 3a: Application of the RBE and the late-effect correction

$$\frac{37}{0.8} = 46.25 \text{ Gy or 3.85 Gy per fraction; } L_d \text{ factor} = 1.037$$

$$\therefore dL_d = 4.00$$

$$N_{4.0} = \left[\frac{18}{4} \times \left(\frac{28}{12}\right)^{0.11}\right]^{1.54} = 11.69 \text{ fractions}$$

where $N_{4.0}$ is the number of fractions of 4.0 Gy for 1800 ret.

$$\mathrm{PT} = \frac{12}{11.69} = 1.03 \text{ (\textit{i.e.} TDF} = 103)$$

Technique 3b: Application of the RBE and the late-effect correction

$$\frac{31.5}{0.8} = 39.4 \text{ Gy in six fractions}$$

i.e. 6.56 Gy per fraction of equivalent ^{60}Co radiation. L_d factor = 1.091; therefore, $dL_d = 7.16$ Gy.

$$\mathrm{N}_{7.16} = \left[\frac{18}{7.16} \times \left(\frac{18}{6}\right)^{0.11}\right]^{1.54} = 4.97 \text{ fractions}$$

$$\mathrm{PT} = \frac{6}{4.97} = 1.21 \text{ (\textit{i.e.} TDF} = 121)$$

Thus, according to the NSD concept the late effects of six fractions of 5.25 Gy of 70 kVp X rays in 18 days should be greater than those of 12 fractions of 3.08 Gy, as was shown in Table V of Dr Bates' article.

For early effects, no L_d factor would be needed and the relative NSD value for the 12-fraction regime was 1766 rets and for the six-fraction regime was 1865 rets, if an RBE correction of 0.8 is used, so that the doses chosen were such as to be within 2–3% of the NSD for equal effects (within the possible 5% error in dosage).

Comparison with the linear-quadratic model

Dr Bates discussed the merits of the NSD and the linear-quadratic concepts relative to the results of her clinical study but derived a value of R (the α/β value) of -0.787 Gy on the assumption that 51 Gy in 12 fractions produced the same effects as 35 Gy in six fractions. This value of R suggests that the regimes were not isoeffective. The α/β ratio is theoretically a constant, whatever the fractionation regime used.

Since $S = \mathrm{e}^{-nd(\alpha d + \beta d^2)}$, where S is the survival after n fractions of d Gy, for two schedules of equal effect:

$$\frac{\log_e S_1}{\log_e S_2} = \frac{n_1(\alpha d_1 + \beta d_1^2)}{n_2(\alpha d_2 + \beta d_2^2)} = 1$$

$$\frac{n_1 d_1}{n_2 d_2} = \frac{R + d_2}{R + d_1^2} \tag{1}$$

(using R for α/β, *e.g.* Bates (1988)).

For example, 31 × 2 Gy and 18 × 3 Gy are isoeffective schedules as used in Oxford and other centres for many years. Both correspond to 100 TDF (*i.e.* a PT of 1) (Orton & Ellis, 1973).

Therefore, it is justifiable to use these schedules in Equation 1 to determine R. From this, $R = 4.75$.

Using the value of R of 3.5 Gy for late effects and substituting into Equation 1 to compare 12 and six fractions for equal late effects:

$$\frac{12 \times 4.25}{6 \times d} = \frac{3.5 + d}{3.5 + 4.25}$$

$d = 6.55$ and $dL_a = 6.55 \times 1.095 = 7.11$

$$Nd = 18 \times N^{0.35} \times \left(\frac{T}{N}\right)^{0.11}$$

$$N^{0.65} = \frac{18}{7.11} \times \left(\frac{18}{6}\right)^{0.11}$$

Substituting in the NSD formula (transposed):

$$N \text{ for } 1800 \text{ rets} = \left(\frac{18}{7.11} \times 3^{0.11}\right)^{1/0.65} = 5.02$$

$$\mathrm{PT} = \frac{6}{5.02} = 1.2 \quad \textit{i.e.}\ \mathrm{TDF} = 120$$

This corresponds to the value derived under the heading Technique 3b.

Therefore it seems that the NSD concept is not invalid and that the NSD formula modified for late-effects is also valid, according to Dr Bates' own results, and that they are consistent with the LQ models.

Yours, etc.,
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(*Received December 1988 and in revised form February 1989*)

(*Authors' reply*)

THE EDITOR–SIR,

Our reply to Dr Ellis is essentially the same as our reply to Dr Tomlinson (Bates & Scott, 1989). The NSD concept correctly predicts the direction of the differences in the late reactions observed, but not the extent of these differences.

Let us concentrate our attention on the late effects in the chest wall, using Technique 3 (Table V; Bates, 1988). At 10 years the skin changes were greater with six fractions, and this is the result which, as Dr Ellis demonstrates, is in accordance with NSD theory. But at 1 year the late changes were less with six fractions, and at 5 years they were precisely equal. Dr Ellis has calculated a TDF of 121 for six fractions and 103 for 12 fractions. We believe that this predicted 17% difference is incompatible with the data.

The case of Technique 1 is not so clear cut, as there were significantly greater effects using 12 fractions at 5 and 10 years. However, Dr Ellis calculates TDFs of 121 for 12 fractions and 99 for six fractions, a 22% difference. We believe that a 22% increase in biologically effective dose would produce a massive increase in damage with the 12-fraction technique, which was most certainly not observed.

We therefore reject Dr Ellis' suggestion that the data are in accord with the NSD concept and stress again that the NSD should not be used when changing down to two fractions per week.

Yours, etc.,
THELMA D. BATES
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(*Received January 1989*)

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Book reviews

Nuclear Medicine Annual 1988. Ed. by Leonard M. Freeman and Heidi S. Weissmann, pp. xii + 339, 1988 (Raven Press, New York), $111.50.
ISBN 0-88167-433-8

The *Nuclear Medicine Annual* for 1988 is the ninth in this series. Unlike the *Year Book of Nuclear Medicine*, it contains a number of reviews on subjects of current interest in nuclear medicine. The articles are of clinical rather than technical interest. The first is from the Guy's group reviewing the value of bone scintigraphy in breast cancer. It gives the background to bone scintigraphy and contains a series of valuable tables on the frequency of bone mestases, the relative efficiency of radiographs, isotope imaging and the relation between positive scans and survival—all useful information in the days of seeking ways of being cost effective. The chapter on single photon emission computed tomography (SPECT) concentrates rather heavily on the liver where this technique is of little clinical value. Although monoclonal antibody imaging and the imaging of infections are mentioned, the potential of SPECT in these areas is not brought out. Captopril renography is reviewed in relation to renovascular hypertension. This useful article is spoilt for the non-expert by excessive use of abbreviations.

Another subject of current interest, radiolabelled antibodies, is discussed with particular emphasis on the future potential. The author gives a refreshingly balanced view of this technique, which has yet to show its potential in imaging studies. The chapter on the diagnosis and therapy of osteoporosis deals with single photon, dual photon and X-ray methods in detail. It is a good introduction for those being persuaded to take up this technique. Of the remaining chapters, the article on the effects of aging on the tests involving the kidneys, endocrine and central nervous systems is the most interesting. Although up to date, studies using the new radiopharmaceutical, Ceretec, are missing.

The book reads well and provides useful summaries of the subjects included. It deserves a place in radiological and nuclear medicine libraries.

V. Ralph McCready

Clinics in Gastrointestinal Ultrasound 23. Ed. by Alfred B. Kurtz and Barry B. Goldberg, pp. xii + 298, 1988 (Churchill Livingstone, New York), £35.00.
ISBN 0-443-08574-9

This 300-page textbook contains eight chapters on the liver, gallbladder, pancreas, spleen and the gastrointestinal tract. There is a chapter on interventional procedures and one on Doppler ultrasound in the gastrointestinal tract. This is the second book in this series on gastrointestinal ultrasound and is intended to provide an update for experienced ultrasonographers and to be useful to those in training.

The text is easy to read and there are numerous good quality illustrations. In each chapter, clinical problems are discussed and the usefulness of ultrasound relative to other imaging methods such as computed tomography, magnetic resonance imaging and scintigraphy is presented in a very sensible and coherent way. However, Chapter 6 on the bowel itself fails to recognize the limitations of ultrasound compared with other imaging modalities in this area. Nevertheless, I would recommend this book as an introduction to gastrointestinal ultrasound and it would be a useful addition to the libraries of departments where ultrasound is taught.

M. Phelan

Imaging Anatomy of the Knee Region. By Henri Sick and Jean-Louis Burquet, pp. x + 88, 1988 (J.-F. Bergmann Verlag, Munich), DM 185.
ISBN 3-807-00373-8 (Munich)
0-387-00373-8 (Heidelberg)

The anatomy of the structures on the posterior aspect of the knee is complex and most radiologists require help with the interpretation of images obtained by computed tomography (CT) and magnetic resonance imaging (MRI). This book gives just the aid that is required.

It is divided into three sections with the first part consisting of a series of images in the coronal plane (called frontal slices), the second part has images in the sagittal plane and the third part, images in the transverse plane (called horizontal slices).

In clinical practice the majority of scans are done for assessment of suspected and proven soft-tissue and bone tumours. This is because the effective local management of these lesions is very dependent on determining the extent of the tumour and its relationship to the major vessels and nerves and thus the transverse images are the most helpful.

The pictures are of high quality and this has enabled clear and precise labelling to be attained. I have tested the atlas whilst I have been reporting cases (it is not the type of book that you can read from page 1 to the end) and have been able to compare the information that can be obtained from other atlases—both radiological and anatomical. The images in this book are the most helpful because of their clarity. It has not been possible to check every label on the figures but I have not been able to detect any errors.

The authors are a radiologist and an anatomist and this collaboration has produced an excellent book, which I can thoroughly recommend for departments where CT and MRI are performed, or where such images have to be interpreted.

B. J. Preston

Diagnostic Imaging. An Algorithmic Approach. By Ronald L. Eisenberg, pp. xx + 713, 1988 (J. B. Lippincott, Philadelphia), £71.75.
ISBN 0-397-58300-1

I must confess that my heart sank a little when I was asked to review this weighty volume of 700-odd pages written by 76 contributors, especially as the title indicated algorithms, which I have never been fully at ease with. In fact I am still not fully convinced about the use of rigid algorithms even, as explained in the text, allowing for the modifications required for local availability, local expertise and developing technology. But this somewhat personal view about algorithms should not detract from the many excellent features to be found in this book.

What Professor Eisenberg has done is to persuade a large number of expert colleagues to write review commentaries about the clinical aspects and imaging management of 47 common clinical problems. And thus this book contains a host of up-to-date imaging strategies. Anybody coming up to the final FRCP would find a lot of useful material here. The book provides exactly the background reading required for the old style, short essay questions. I for one learned a lot.

Inevitably there is wide variation in the style, content and clarity of the individual chapters. I imagine that each author was given a blueprint to follow: introduction; clinical findings; diagnostic evaluation; description of modalities (their word, not mine); general radiographic approach; bibliography (largely American); algorithms. Some authors have stuck to this quite rigidly; others have not. I sense that editorial control has been diplomatic, mainly ensuring that major overlap was eliminated. Despite this, a section on lymphography is reproduced word for word in the chapters on the prostate and bladder.

There are many statements and features which intrigued me (over and above the differences between practice in the UK and USA). The section on pulmonary embolism is informative although all roads seem to lead to arteriography! Myelography for posterior mediastinal masses seems surprising when magnetic resonance is offered very early for many less deserving problems. It is good, in the same chapter, to be reminded of the need to assess the oesophagus in every such case. Ultrasound is surprisingly relegated to a low position in the list for imaging hepatic masses. For a patient with a right lower quadrant mass in whom appendicitis/mass is suspected I was surprised to see an arrow leading straight to surgery; many might drain such lesions percutaneously. I am not sure that "excretory urography remains the initial screening examination of renal masses" any more. I am anxious that renal calculi might be missed in children with urinary tract infections; the plain abdominal radiograph did not feature much. In the section on adrenal masses, MIBG studies have a rather low profile. If the plain radiographs are normal in a patient with back pain, computed tomography (CT) should be performed if there are medicolegal implications! A negative CT scan appears "inconclusive" in the investigation of headache; MR is still necessary!

The part of the book devoted to cancer staging was especially good. It is interesting to see how some authors have now abandoned lymphography (as we have) while others still make a case for its retention. In the miscellaneous section it seems odd that there was considerable discussion about the use of Doppler in deep vein thrombosis but little consideration of direct demonstration of compressibility by real-time ultrasound.

The above comments are not criticisms; they merely reflect the fascinating variation in practice amongst differing institutions. Indeed comparing one's own strategies with those recommended here is one of the most intriguing facets of the book; it certainly provides food for thought. The volume is handsomely produced with excellent illustrations and virtually no typographical errors. Compared with the price of other radiological books it represents pretty good value. Although this work has many excellent features, its novel design may put off potential purchasers. So, too, may the inevitability that some sections will be out of date within 5 years. This latter point can be addressed by further editions which I, for one, would look forward to.

ADRIAN K. DIXON

Current Trends in Orthopaedic Surgery. Ed. by S. B. Galasko and J. Noble, pp. x + 252, 1988 (Manchester University Press, Manchester), £35.00.
ISBN 0–7190–2535–4

This moderately priced and sized volume covers many topics which will be of great interest to orthopaedic surgeons, especially, I would have thought, those in training. There are some gems: Freeman and Railton on knee prostheses, Neer on shoulder arthroplasty and Galasko on the treatment of skeletal metastases. Some of the many topics are less well covered, as is inevitable in multi-author volumes.

The chapter on magnetic resonance imaging in musculoskeletal sarcoma is perhaps a little too short to be of great benefit to radiologists and, in the chapter on congenital dislocation of the hip, no mention is made of the role of ultrasound in the diagnosis, nor of the changes in the management of patients brought about by the use of this modality. It is questionable whether X-ray examination in infancy is as helpful, but at least the matter should be debated. Neither Graff nor Catterall is mentioned in the references.

One name that stands out in this volume is that of the late Sir Harry Platt, whose influence obviously still lives on in Manchester. His life and career are well described, as is that of his pupil Sir John Charnley. What wonderful men they were—how sorry I am never to have met them.

This well produced book is a good read and should find a place in your hospital library. Those in search of more detailed knowledge must seek it in a larger monograph.

P. RENTON

Modern Neuroradiology. Volume 3: Computed Tomography of the Head and Neck. By Thomas H. Newton, Anton N. Hasso and William P. Dillon, pp. xii + 468, 1988 (Raven Press, New York), $169.00.
ISBN 0–88167–392–7

Head and neck radiology implies the radiology of those regions above the shoulders which are not the prime concern of the neurosurgeon and are thus deemed within the remit of the general radiologist, rather than the neuroradiologist. There are inevitably "grey areas" and this volume, despite being in the *Modern Neuroradiology* series, will be of interest to all radiologists working with computed tomography (CT).

The authors are acknowledged experts in the field. The majority are American, but happily four contributors originate from Europe. The book is well bound and printed on high quality paper. Each chapter is profusely illustrated to a high standard and detailed perusal of the figures revealed only one error (Figure 5-28) where the caption was incorrect. The superior vestibular nerve is posterior to the facial nerve, not anterior. The reviewer was unable to find references to any articles later than 1985, but suspects the reason to be that the important descriptive work on CT had been completed by this time. After 1985, magnetic resonance imaging comes to the fore in the literature.

One need really look no further for a text on head and neck radiology than this excellent treatise. It can be warmly commended and should find a place in every CT library.

P. BUTLER

Radiology of AIDS. Ed. by Michael P. Federle, Alec J. Megibow and David P. Naidich, pp. xiv + 163, 1988 (Raven Press, New York), $111.50.
ISBN 0–88167–406–0

This textbook, written by three authors with unrivalled experience in the clinical and radiological manifestations of AIDS, is an excellent reference book for those seeing the occasional case and those with a larger clinical practice. It is not an easy read, it is packed full of fact and extensively referenced, including recent (1987) publications from both America and Europe.

The initial chapter discusses the epidemiology, immunological deficiencies and clinical presentation of both AIDS and ARC. The brief description of the opportunistic infections which may occur is well done and very useful to those whose microbiology is somewhat limited. There is also a description of the therapeutic agents, and their mode of action, that have been used in the treatment of this disease. The major part of the book is devoted to chapters on neuroradiological pulmonary and gut changes which may be found in these patients. Paediatric AIDS and its manifestations are covered in a separate chapter.

The material and presentation are good and the ultrasound, computed tomography and radiological illustrations are clear. This is particularly praiseworthy as many of these patients are extremely ill and difficult to image. Throughout the chapters, the pathological appearances both micro- and macroscopic with explanatory text, are closely integrated with the imaging figures. The final chapter and appendices are concerned with the antiseptic precautions needed when dealing with HIV and suspected HIV-positive patients and material. The appendix dealing with CDC (Center for Disease Control) definitions and criteria is not particularly relevant to radiologists.

This, even for those who may see a very limited number of AIDS patients, is a book worth buying for the department library.

J. A. Gleeson

Cranial Computed Tomography and MRI, 2nd edn. By S. H. Lee and K. C. V. G. Rao, pp. xiv + 858, 1988 (McGraw-Hill, New York), £125.00.

ISBN 0–07–037459–7

Magnetic resonance imaging (MRI) has become an important neurodiagnostic modality during the 4 years since the first edition of this textbook of cranial computed tomography (CT), and the authors have attempted to integrate magnetic resonance imaging (MRI) into their second edition.

A very good simplified account of the physics of MRI and the normal appearances of MRI images of the brain and orbit are added to the descriptions of CT in the first two chapters. The following 13 chapters, dealing with the orbit and the various conditions involving children and adults, are virtually unchanged from the first edition, apart from the addition of one or two illustrations of MRI appearances and a very brief comment on its contribution to diagnosis. A chapter on pitfalls and limitations is confined to those of computed tomography in neurodiagnosis.

There is, however, an excellent final chapter by William Bradley and Keith Kortman dealing with the current clinical application of cranial MRI, which is well written and beautifully illustrated and supplemented with well chosen references.

Much of the unchanged part of the book is sufficiently up to date to require very little modification if one considers most of the chapters in conjunction with the addition of MRI. However, it is a pity that the opportunity to modify the few deficiencies was not taken. These include a certain amount of overlap, which is particularly evident in the chapters devoted to paediatric neuroradiology. The chapter on cranial cerebral anomalies would benefit from a concise account of the disordered embryology and a clear statement of the features necessary for the diagnosis of particular conditions. An essay including most of the features which may be present tends to leave the student with a rather confused overall view of the subject, rather than a clear understanding of its essentials.

It is, of course, of interest and importance to indicate the place of other types of neuroradiological study, especially when these studies are necessary to supplement, confirm and particularly to emphasize the underlying basis of CT and/or MR images which are being illustrated. It does, however, appear totally unnecessary to refer to studies which have been rendered obsolete by the new technologies and are now of historical interest only. A few of the prints, which were obviously of poor quality in the previous edition, have been reprinted without modification. However, despite these few adverse comments, the book has considerable merit as a text for neuroradiologists and other neuroscientists in training, and as a reference book for general radiologists who are called upon to report CT and MRI brain scans. Though reasonable value for money, it is rather expensive for individual purchase; it is recommended for departmental and medical libraries.

Brian Kendall

Practical Guides for General Practice 3. Radiology. By Robert F. Bury, pp. x + 90, 1988 (Oxford University Press, Oxford), £4.50.

ISBN 0–19–261681–1

This is an excellent book. It is small, readable and cheap, and contains a lot of simple information which will be of great interest and value to every GP who picks it up, even if he only reads part of it, which is unlikely.

It is also of great interest in another way. The author has taken on the philosophy that, as every patient "belongs" to a GP, it is very important that not only GPs know what is likely to happen to their patients in hospital but also that GPs should recognize the radiologist as a front-line hospital referral specialist, whose proper use of very expensive diagnostic equipment can expedite the solving of patients' problems, and provide a much faster and better service to patients than the alternative referral to X-ray (imaging) departments only via medical or surgical outpatient departments. Those radiologists whose interest or training does not let them enthuse over the provision of a service with direct responsibility for the clinical care of patients may not appreciate this, but there can be few radiologists who would disagree with the philosophy that the radiologist should "tell" the patient their findings where this is clinically appropriate. Are we doctors or technicians?

I would criticize the book in one respect; the author has followed the conventional approach concerning the so-called hazards of X radiation. Now that we have had nearly 100 years of diagnostic radiation I think it is time that people researched what the real hazard of diagnostic radiology is, if any, rather than continuing to extrapolate ideas from some unfortunate nuclear explosions. If I read Table 2.4 correctly, if a patient receives 18 000 barium enemas he will develop cancer. Has this actually been proved?

Apart from the philosophy, the book has a second great merit—its recognition of the value of ultrasound. Possibly, so far, ultrasound has not received recognition as a diagnostic technique whose importance may well exceed that of X radiation. The book embodies references to the use and value of ultrasound throughout, but perhaps underplays the cheapness with which ultrasound can provide significant diagnostic information. The rapid development of cheap electronic apparatus means that an ultrasound machine could be found side-by-side with an electrocardiograph in every doctor's surgery, and it only needs one manufacturer to mass-produce a simple, cheap ultrasound set for the world of medical diagnostic imaging as we know it today, to change. Who remembers how much the first TV set cost?

In summary, books like this are rare. Perhaps its author unwittingly stumbled upon the difference between information and wisdom! This book should be issued by every Family Practitioner Committee to every doctor—and its effects monitored. That would make for some interesting research.

A. E. Hugh

Cerebral Visual Disturbance in Infantile Encephalopathy. By O. van Nieuwenhuizen, pp. xiv + 204, 1987 (Martinus Nijhoff/Dr W. Junk Publishes/Kluwer, Dordrecht), £50.50, US $64, Dfl 145.
ISBN 0–89883–860–0

The author of this book set out to discover whether there were any characteristic investigative findings in children with centrally mediated visual deficits that would perhaps help in the earlier identification of such deficits.

Twenty-six children and young adults were extensively investigated with detailed neurological and ophthalmological examinations, neuroradiological (computed tomography (CT) scans in all and magnetic resonance imaging (MRI) scans in five) and neurophysiological (opticokinetic nystagmography and visual evoked potentials) examinations. The results of these are clearly set out for each individual. Each CT or MRI scan is well produced with a supplementary diagram detailing the general and specific abnormalities shown. The reproduction of the results of the opticokinetic nystagmographic studies might, however, have been left out as they add little, except perhaps for the cognoscenti.

The early chapters review comprehensively the little previous work in this area. The electrophysiological techniques to be used are clearly explained but the text of this book is marred by the overuse of some rather unconventional and not always adequately explained abbreviations. I am uncertain as to whether the introduction of the term infantile encephalopathy is helpful except in that it emphasizes the fact that children with one manifestation of early brain damage, *e.g.* cerebral palsy, often have other handicaps, including visual problems, which are more difficult to identify in them and may further prejudice their developmental progress.

The results are helpfully summarized in the last chapter. However, all these tests will usually only be confirmatory as the earliest and best way of determining the visual status of *all* infants is to ask their parents. This is confirmed by this book—in only one case did professional diagnosis precede parental concern.

The book is rather too expensive an introduction for the individual buyer but the beginner wishing to know more about cerebral visual disturbance will find it a book to borrow from the library and follow up particular references from the bibliography on anything that interests him.

C. P. WHITE

Contrast Media. By Denis H. Carr, pp. xii + 227, 1988 (Churchill Livingstone, Edinburgh), £45.00.
ISBN 0–443–03352–8

The publishers are inserting an erratum slip in this work; the cover and title page should have read "Edited by".

The introduction says that this book "is not intended to be all embracing, but rather an overview of the uses and problems associated with contrast media". There are 19 chapters by 26 authors, making up a collection of interesting, varied essays on parenteral contrast media. Barium and other enteral agents are not considered.

The volume begins with basic pharmacology and ends with paramagnetic contrast agents. In between there is a wide range of topics. Six chapters are concerned with adverse reactions, toxicity and risks. Among these, Harry Fischer's is particularly impressive: a painstaking review of the evidence on contrast medium reactions, with some 200 references. Fischer says bluntly "we do not know what causes adverse reactions" at the end, and makes a good case for the research laboratory in advancing understanding. Discussion of the new low-osmolar media is naturally to the fore in these sections. The remaining two-thirds of the book are concerned with particular clinical areas and techniques, where a bevy of experts looks at developments in each field: angio, CT, neuro, etc.

In a multiauthor work like this there is bound to be a variety of styles and emphasis. The chapters report their authors' preoccupations, much as the proceedings of a conference. Overlap and repetition have to be traded for the pleasure of stimulating radiological company. Ivan Moseley (National and Moorfield's) on neurology and eyes, Judith Webb (St Bartholomew's) on kidneys, Dennis Stoker (Royal National Orthopaedic) on joints: I have picked three especially enjoyable riders to show that this is a fine race card. The book is full of interest in giving multiple views on what is important in 1980's contrast media. Cost, one of the most pressing topics, does not appear in the index, though Drs Raphael and Donaldson (National Heart) give a useful £/g of iodine table. This is a rewarding, well produced volume.

THOMAS SHERWOOD

Rheumatologic Disorders. Advanced Exercises in Diagnostic Radiology 19. By L. F. Layfer, J. Petasnick and R. S. Katz, pp. viii + 186, (W. B. Saunders, Philadelphia), £18.50.
ISBN 0–7216–2385–9

Although I have not been impressed by the other books in this series, I feel this volume is of value. The book is titled as *Rheumatologic Disorders*, but, in fact, includes other related conditions, particularly in the spinal chapter. There is a good section on the approach to joint disease divided into the basic appearances and then the use of these to form a clinical diagnosis. The second section of the book is a series of exercises with the relevant radiographs. These question the reader and give comments as well as answers, which are good; the radiographs are very good and the book is well indexed.

This is a very useful book for the radiologist in training but, as stated in the preface, it is not the complete answer, paticularly with reference to examinations. Some conditions necessary for different diagnosis, for example haemophilia and tuberculosis, are undercovered. This is of clinical importance as are some of the metabolic deposition arthritides that are completely absent.

Nevertheless, this book is a very worthwhile read for all radiologists in training, containing much useful information, which is presented in an easily assimilated form.

DAVID FINLAY

Oxford Medical Engineering Series, 7: Blood Flow in the Brain. Ed. by W. J. Angerson, C. D. Sheldon, J. C. Barbenel, A. C. Fisher and J. D. S. Gaylor, pp. xiv + 138, 1989 (Oxford University Press, New York).
ISBN 0–19–857646–3

This book contains a selection of 17 papers from the 26th Annual Scientific Conference of the Biological Engineering Society, which was held at the University of Strathclyde in 1986. The first seven papers are concerned with imaging of cerebral perfusion using radiophamaceuticals, in particular the recently developed tracer ^{99}Tc^{m}-HMPAO. Topics studied include the mode of uptake of ^{99}Tc^{m}-HMPAO, the relationship between uptake and cerebral perfusion and the potential value of tomographic imaging of this radiopharmaceutical in the investigation of cerebral tumour and dementia. The remaining papers largely deal with the role of Doppler ultrasound in the investigation of cerebral arterial disease. Subjects studied range from the relative merits of duplex scanning and intravenous digital subtracton angiography in carotid artery disease to the response of the intracranial vessels to cigarette smoking.

On the whole, the book reads well. The articles are presented in a logical sequence and despite the often similar subject matter there is little repetition in the text. However, as with many collections of conference papers, the depth in which individual contributors cover their subject matter is variable. Papers range from three to 16 pages in length. Most articles are adequately supported by tables, graphs and illustrations. One paper that describes colour-coded Doppler ultrasound contains six colour photographs. The quality of reproduction of illustrations is generally high, although the clarity of some of the Doppler ultrasound images might have been improved by labelling.

My main criticism of the book is that it fails to fulfil a particular need; it has neither the breadth of a standard text on cerebral blood flow nor does it cover individual topics in the depth of a scientific paper. Furthermore, as 3 years have now passed since this collection of articles was originally presented, similar material has been published elsewhere. For example, a far more comprehensive review of the mode of uptake and the potential clinical applications of ^{99}Tc^{m}-HMPAO is contained in a supplement to the December 1988 edition of the *Journal of Cerebral Blood Flow and Metabolism.*

In summary, although this book provides some useful background reading for individuals interested in the investigation of cerebral blood flow, more detailed information is available elsewhere. It is unlikely to be a valuable addition to the departmental library of a radiology department.

P. J. GOULDING

Radiological Safety Aspects of the Operation of Proton Accelerators. Technical Reports Series, No. 283. By R. H. Thomas and G. R. Stevenson, pp. xii + 473, 1988 (International Atomic Energy Agency, Vienna).
ISBN 92-0-125188-2

In view of the renewed interest in the use of protons for radiotherapy and the development of hospital-based accelerators for both the production of protons and fast neutrons, this book is to be welcomed. The subjects covered include radiation measurements at accelerator facilities, radiation shielding, a description of some typical installations and the impact on the environment of the use of these machines. It is obvious that the authors have drawn widely on their own considerable experience of the problems of radiation shielding and measurements at proton accelerators and have produced an extremely detailed review of their subject.

The book is well written and clearly presented with a comprehensive reference list, which, together with the chapter dealing with sources of information, makes the book an excellent starting place for someone new to the field; it will also be of great assistance to those already engaged in radiological aspects of accelerator safety. For those dealing with the medical applications of protons it might have been useful to have had a specific section dealing with the shielding and labyrinth design for accelerators producing proton energies of the order of 250 MeV. As it is, the book deals with protons over a vast energy range from a few tens of MeV to a few hundreds of GeV and much of the information required for designing shielding for medical applications is covered in the text.

The chapters on radiation shielding and radiation measurements at accelerators are particularly helpful, whatever the energy of the machine. In the latter, however, the authors have failed to take into account recent developments in microdosimetry for radiation protection purposes and dismiss LET spectrometer instruments too readily. The problems of lack of sensitivity that they cite can readily be overcome by the design and size of the detector. This is possibly the only major omission in an otherwise very thorough book.

The one aspect of the book that was the least helpful was the inclusion of the health and safety manual from the Lawrence Berkeley laboratory and with it such detail as the safety of microwave ovens. At best this could have been given as an appendix, if not omitted altogether.

Despite these criticisms this is an excellent book that will surely become a standard reference in the field of accelerator safety. Its interest will, however, be specific to those involved or interested in the design and operation of particle accelerators and perhaps would not find a place on the shelves of a general radiotherapy library.

D. E. BONNETT

Advances in Urologic Oncology. Progress in Clinical and Biological Research, Vol. 277. Ed. by Nasser Javadpour and Gerald P. Murphy, pp. x + 150, 1988 (Alan R. Liss, New York), $48.00
ISBN 0-8451-5127-4

This book covers in considerable detail some of the major topics in urological oncology. The text is aimed primarily at urologists practising in the field of clinical oncology. The contents comprise a series of papers given at a symposium on urological cancer held in Baltimore in 1987. The Editors aim to compile an in-depth study of recent advances in the diagnosis and management of genito-urinary tumours.

The first part of the book covers a variety of subjects, which includes progress in the pathology of urinary tract neoplasms, concentrating on tumours that have previously been regarded as benign. Also discussed in separate chapters are the role of lasers in urology, continent urinary diversion and the results of chemotherapy in advanced urothelial check tumours using the M-VAC regime.

The second part seeks to provide a thorough review, in a series of chapters, of the effective management of testicular, prostatic, bladder, adrenal and renal cancer. Selected advances in the therapy for urological cancer including gonadotrophin releasing factors; biological response modifiers are discussed separately, along with an evaluation of the paracrine and endocrine effects of genito-urinary tumour-produced growth factors.

As with many multiauthor texts compiled as a result of a symposium, the book does not read particularly well and there is much variation in style and layout techniques. Because such a large number of often unrelated subjects are covered, the book fails in its aim to be comprehensive in any particular area of urological oncology. There is a tendency for the text to concentrate on specific types of treatment, which could well be misleading for the reader who is looking for a review of the subject. It does, however, provide excellent details of certain specific advances in urological oncology which are not covered in other texts. I found the chapter on the role of ureteroscopy in the management of urothelial tumours stimulating and this will be of particular interest to all clinicians involved in the diagnosis and treatment of upper urinary tract tumours. It is clear, however, that several of the chapters, particularly those concerned with chemotherapy, are already appearing slightly dated in this very rapidly changing field.

This book would be a useful reference text for a library but would have limited appeal to readers other than clinical urological oncologists.

P. H. POWELL

Dosimetry in Radiotherapy Vols 1 and 2. Proceedings of a Symposium. Vienna, 31 August–4 September 1987, organized by IAEA in co-operation with WHO, pp. x + 385 (Vol. I); xiv + 394 (Vol. 2), 1988 (International Atomic Energy Agency, Vienna), ASch 800.
ISBN 92–0–010088–0 (Vol. I)
92–0–010188–7 (Vol. 2)

It is not possible to do justice to a review of the proceedings of a meeting of delegates from 34 countries covering 48 papers and 37 posters, but most readers will find something to interest them in these two volumes. The meeting was the IAEA Symposium on Dosimetry in Radiotherapy in 1987 and covers the whole gamut from the establishment of international standards of dose to the output of the treatment machine, from the dose profiles in the TBI patient to the dose per pulse in the very high-energy accelerator. The meeting was divided into eight sessions.

Two sessions were devoted to the determination of absorbed dose and concentrated on the establishment of dose standards and their protocols. There are several papers discussing perturbation effects in differently shaped ionization chambers and different beam modalities including orthovoltage X rays and electrons. A later session was given to the establishment of national standards. The new facility at the NPL (UK) for megavoltage X-ray beam dosimetry using a graphite calorimeter is discussed, the energy being specified in terms of the TPR 20/10. Another paper looks at the problems of using a water calorimeter and the water defect. Posters report the results of national and international postal checks on equipment calibrations and others look at the long-term stability of secondary standard instruments.

The session on dosimetry in brachytherapy deals with interstitial therapy, using iridium 192 and iodine 125, and intracavitary gynaecological treatments. The invited paper retraces the history behind the changes from mass of radium to the currently popular air kerma rate, and provides data on a variety of nuclides and iridium 192 in particular. Another French paper discusses the application of the Paris system, based as it is on continuous line sources, to discretely loaded source trains. Quality assurance in brachytherapy is covered in some detail in the context of gynaecological treatments. In addition to the simplification of batch wipe testing, the author discusses the need for, and pitfalls of, regular dosimetry checks.

External therapy dosimetry was next and almost entirely given over to electron beam therapy—the exceptions being two papers on small (less than 3 cm square) X-ray beams for use in stereotactic radiation therapy. The electron papers covered the contamination of cobalt-60 beams, the effect of bone on depth dose, the spectral distribution of electron energy at depth and the use of film as a dosemeter.

The second volume opens with an invited paper summarizing the dose calculation methods used in radiotherapy (beam) planning. Starting with the basic concepts of isodose curves, the paper develops from the basic cartesian grid of dose points through a variety of beam models to those involving inhomogeneities. The subsequent papers deal with the complexities of three-dimensional planning in both external beam and intracavitary therapy. Among these money-no-object computer installations requiring "three-man-days to develop a 3-D plan" comes a paper describing RTP on an IBM PC with a 1-min computational time. An analysis of the data collected by the ESTRO inquiry into TBI from 34 European countries opens the TBI session and highlights some of the pitfalls and makes recommendations on almost every aspect of the technique. In particular it advocates the AP/PA treatment in a vertical beam, and the second paper proceeds to describe the installation of two 4 MeV accelerators in just that format with a source-to-source distance of 4.1 m covering a field of $200 \times 75\,\mathrm{cm}^2$. The remainder of the session was given over to three papers on phantom measurements and two on *in vivo* measurements using TLDs and semi-conductors.

The concluding session was on conformation therapy. The first paper describes the tracking cobalt unit and the benefits of asymetric or multisegment diaphragms in this context. The dynamic treatment facility using a Philips linear accelerator is the subject of the second paper. The final papers outline the virtues of the multileaf collimator and of the scanning electron and photon beams available on the fourth generation accelerators. Data is presented on the Microtron 50 MeV Race Track accelerator.

The final 15 posters cover a range of subjects from synthetic diamond detectors, neutrons and quality assurance to basic organizational aspects of dosimetry in radiotherapy.

Posters almost by definition rely on their visual impact to get their message across, but when summarized in the proceedings, many appear without any visual material and sadly the reader is denied much of the information.

These two volumes should be available on library shelves for reference. Much of their contents will be outside the immediate experience of many of us, but where it is directly relevant the reader will find a great deal of interest and will benefit from its study.

C. K. Bomford

Radiopharmacy and Radiopharmacology Yearbook 3. Ed. by P. H. Cox, pp. xii + 347, 1988 (Gordon and Breach, New York), \$145.00 (List price); \$74.00 (S.A.S. price).
ISBN 2–88124–670–2

The aim of the book is to provide concise information concerning recent developments in the radiopharmaceutical sciences. There are five main articles which cover reporting of adverse reactions in Europe, a study from the Netherlands relating to the absorbed radiation dose from nuclear medicine investigations, the effect of drugs and concomitant therapy on the biodistribution of radiopharmaceuticals, formulation controls and preliminary clinical studies conducted with $^{99}\mathrm{Tc}^{m}$-3-iodo 2,4,6-trimethyl IDA and a review of the radiopharmacology of immunoglobulins with special emphasis on monoclonal antibodies. In addition there are a large number of selected abstracts covering a wide range of topics. In selecting these abstracts, the emphasis has been on those articles appearing in clinical journals. Based on previous comments to the editor there is now a review of the selected abstracts, and since there are 250 abstracts, a concise summary of the abstracts is a welcome addition to the yearbook. At the end of the book there is a section dealing with new pharmaceuticals, which gives the specification of these preparations, a list of manufacturers of labelling kits and radiopharmaceuticals and a list of relevant books which have recently been published.

The articles have all been well written and they present data in a clear and readily accessible form. I would certainly direct anyone with an interest in radioimmunoscintigraphy and therapy using monoclonal antibodies to the review article by G. Westera, which appears on pages 53–114 (88 references).

In summary, the book represents good value for money since it contains a large amount of readily accessible information. I feel it deserves a place on the bookshelf of any radiopharmacy.

A. W. J. Stuttle

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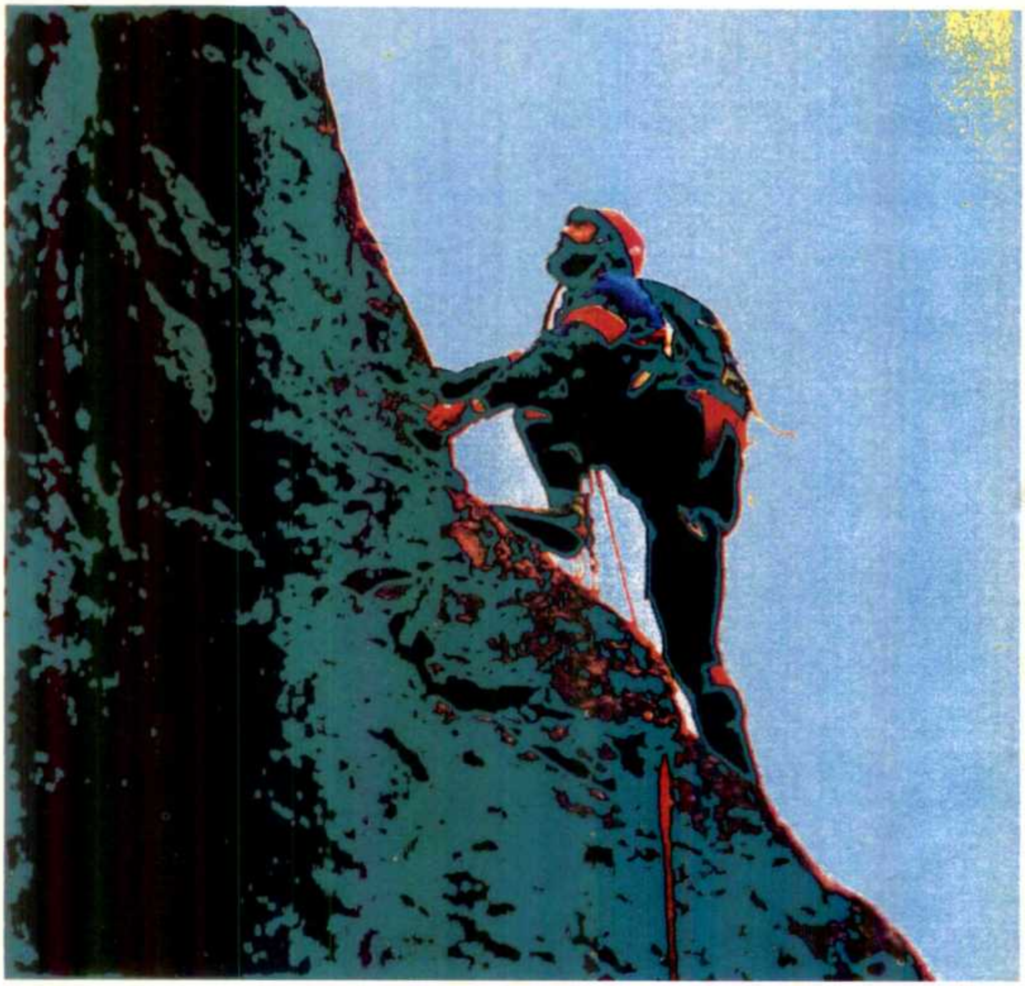

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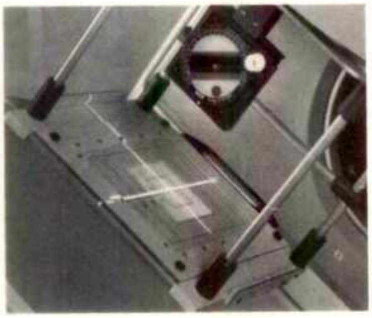

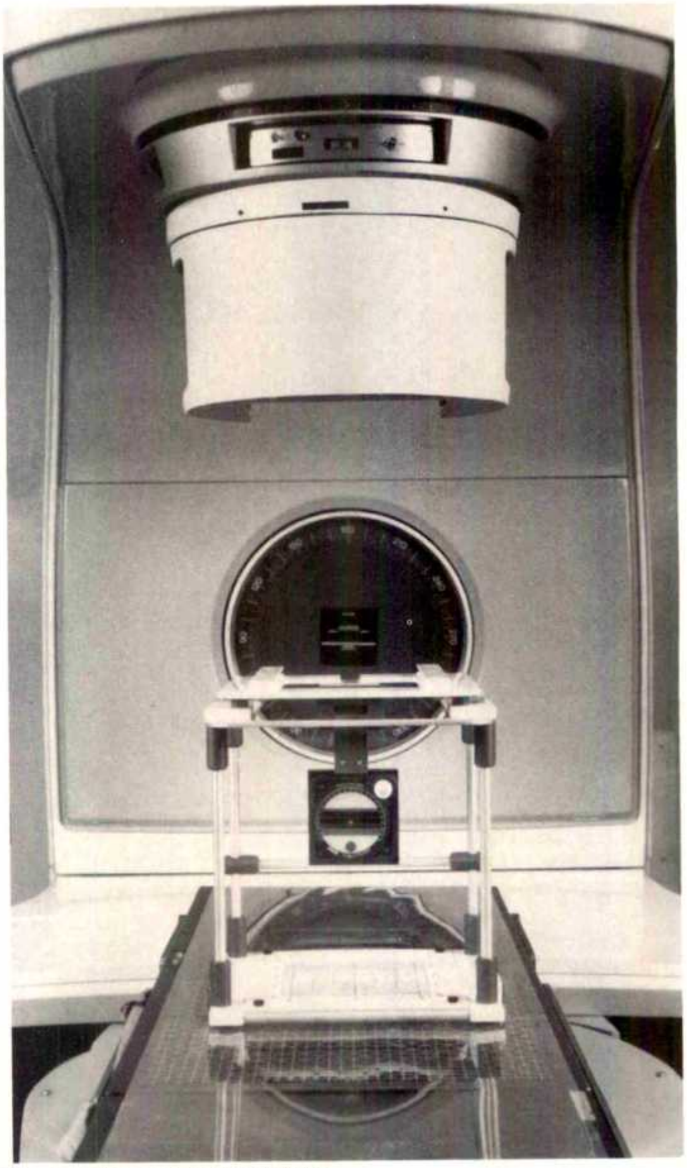

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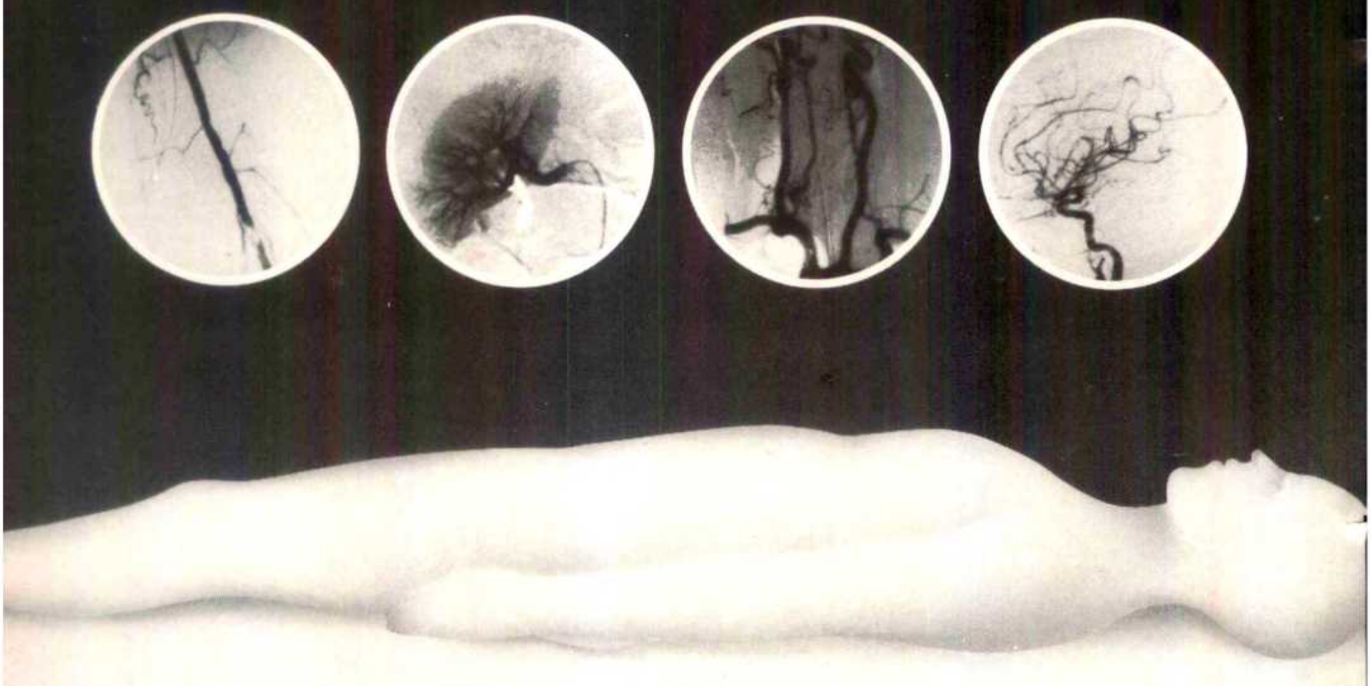

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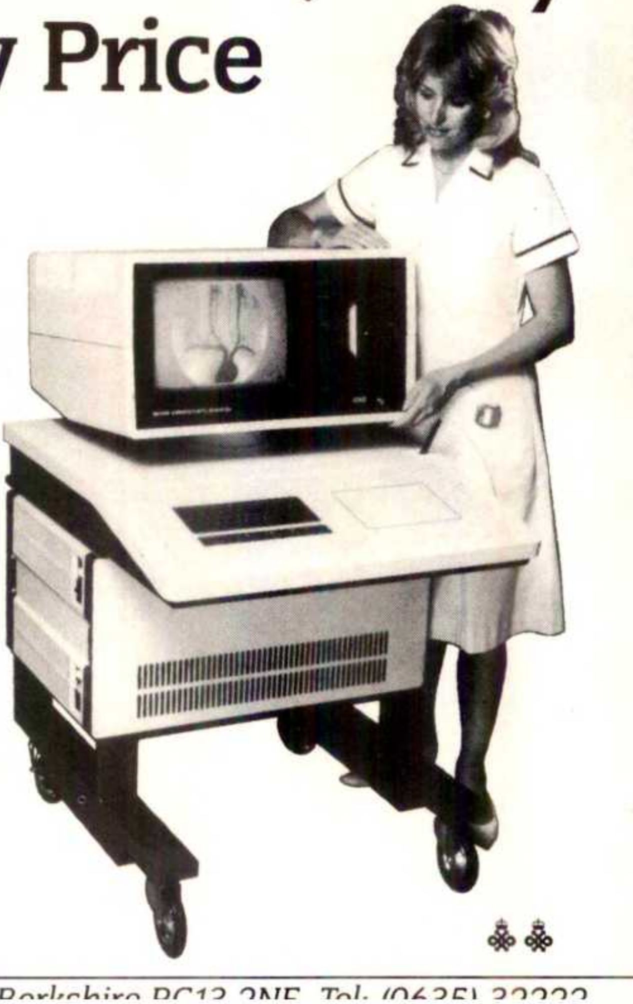

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Proceedings of the 47th Annual Congress of The British Institute of Radiology

Pathophysiology of Disease: Insights from Magnetic Resonance

Chairman: Prof. B. S. Worthington

Multiple sclerosis: steps towards a new understanding
  G. Du Boulay
The assessment of tissue perfusion in brain disorders
  R. E. Steiner, G. M. Bydder and I. R. Young
The analysis of normal and disordered cerebrospinal fluid dynamics
  B. S. Worthington
What is magnetic resonance spectroscopy telling us about human disease?
  D. Gadian

Multiple sclerosis: steps towards a new understanding

G. H. du Boulay, P. S. Tofts and W. I. McDonald
Institute of Neurology, National Hospital, Queen Square

Magnetic resonance, using a meticulously tuned image and with the collaboration of a large team for whom there is no acknowledgment space, reveals much about multiple sclerosis (MS). Multiple cerebral lesions already exist in 60–80% of patients presenting with their first episode of isolated neurological disturbance. Serial follow-up shows that the relative risk for the development of MS within 12–18 months for those with multiple lesions is high (6.8 in optic neuritis, 36 in isolated spinal cord syndromes). T_1 and T_2 data, not only in established MS, but probably also at the time of the first clinical symptom, show that the white matter between the visible lesions is abnormal. Such data can assist in differential diagnosis. Abnormal signal in the acute lesion probably arises from oedema and in the chronic, partly from astrocytes and partly from an increase in extracellular water (greater than anticipated from electron microscopy). Enhancement in multiple lesions in patients with clinically definite MS decreases within 3–5 weeks and disappears in ~80%. New lesions all enhance and gadolinium-DTPA can reveal undetected lesions. New lesions enhance uniformly and more rapidly than older ones, which show as rings. Gadolinium-DTPA tends to spread out into the area around plaques where, on T_2-weighted images, there is diffuse high signal. Ring-enhancing lesions may be seen to enlarge over periods of weeks. Corresponding to the edge of the ring there is often a band of tissue showing shortened T_1 in plain scans, perhaps related to the presence of myelin breakdown products. The effect of high-dose intravenous methyl prednisolone on clinically definite MS patients' plaques observed in two scans 15 days apart shows no visible change or T_1 or T_2 alteration, but T_1 of normal-appearing white matter and T_1 and T_2 of cortex is lowered.

The assessment of tissue perfusion in brain disorders

Robert E. Steiner, Graeme M. Bydder and Ian R. Young
NMR Unit, Hammersmith Hospital, London W12 0HS

By using two spin–echo (SE) pulse sequences (SE 1500/200) with the second sensitized to flow by the use of unipolar gradients on either side of the 180° pulse, it is possible to obtain a phase map in which signal intensity is proportional to capillary blood flow in a particular direction. The pulse sequence is gated to diastole using electrocardiography to reduce the effect of pulsatile cerebrospinal fluid (CSF) motion. This technique was used in a number of normal infants aged less than 1 year demonstrating central and peripheral distribution of perfusion in the brain. Marked changes were also seen in the CSF. Eleven infants with various disorders, haemorrhage, infarction, periventricular leukomalacia, hydrocephalus and meningitis were studied. In this group of disorders, focal deficits were seen beyond the region of abnormality demonstrated with conventional T_2-weighted spin–echo sequences in eight patients. The technique was also used to look at perfusion in 60 adults with a variety of pathology, *i.e.* brain tumours, vascular disease, arterio-venous malformations and epilepsy. In these patients too perfusion abnormalities were demonstrated which were very obvious on the phase maps but were not obvious on T_2-weighted spin–echo sequences. The spatial resolution of the MRI technique is considerably better than that obtained by positron emission tomography and single photon emission computed tomography. It also provides directional information about capillary flow. The technique is totally non-invasive requiring no pharmaceutical intervention of any kind. It can be added to basic MRI screening examinations for structural abnormalities and is suitable for serial studies. The perfusion technique is vulnerable to motion artefacts which can result in unacceptable degradation of the phase maps. As yet it has not been possible to quantify the changes in cerebral perfusion but the use of several different pulse sequences may make this possible in the future. Examples of the various perfusion patterns in the normal and different diseases are presented.

The analysis of normal and disordered cerebrospinal fluid dynamics

B. S. Worthington
Academic Department of Radiology, Queen's Medical Centre, Nottingham

Approximately 500 ml of cerebrospinal fluid (CSF) are secreted each day, largely by the choroid plexus within each lateral ventricle, and this circulates through the ventricular system and the cerebral and spinal sub-arachnoid system being absorbed by the arachnoid villi of the dural venous sinuses. Superimposed on the slow net circulation of CSF are cardiac and respiratory dependent pulsatile flow which can be identified on magnetic resonance imaging by "time of flight" as well as reversible and irreversible phase effects. Bulk flow of CSF within the ventricular system and sub-arachnoid space can be displayed in real-time employing high-speed echo planar imaging. Cardiac-dependent CSF motion occurs secondary to cerebral perfusion and the existence of a third ventricular pump (O'Connell, 1943) has been largely confirmed from radiological studies. An alternating caudal and cranial flow of CSF within the midline ventricular system results in a net displacement into the cranial sub-arachnoid space. The rate of flow is maximal in the aqueduct and on T_2-weighted spin–echo sequences a flow void may be seen; the greatest relative signal loss is seen in normal pressure hydrocephalus and least in atrophy, and this is thought to reflect differing degrees of ventricular compliance. Within the spinal canal, flow is directed cranially dorsal to the cord and caudally ventral to it. In thecal stenosis the pulsation may be reduced or absent and this is a useful indicator of significant compression. Within non-neoplastic cord cysts the fluid may pulsate in a similar fashion to the surrounding CSF or be non-pulsatile. Shunting can both reduce cyst size and eliminate pulsation.

Reference

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What is magnetic resonance spectroscopy telling us about human disease?

D. G. Gadian
Hunterian Institute, Royal College of Surgeons of England, London

As a clinical research technique, magnetic resonance spectroscopy can provide important new information and pose interesting questions about the metabolism of normal and diseased tissue. This was apparent from the early ^{31}P studies of muscular exercise and of cerebral energy metabolites in neonates. More recent studies using new methods of localization on whole body systems raise further questions about liver, brain and tumour metabolism. For example, why do tumours have a normal or sometimes alkaline pH, and what is the significance of an elevated phosphomonester signal in disease? What are the biochemical changes that take place in response to therapy, and how can they be exploited? Further information is available from parallel studies of biopsy samples, body fluids, cell cultures and animal models of disease, and a more detailed picture of tissue metabolism is emerging as techniques evolve. Technical advances continue to be made, for example in localized techniques, in the quality of ^{1}H spectroscopy, particularly of the brain, and in the measurement of absolute as well as relative concentrations. In addition, developments in ^{1}H imaging have an impact on spectroscopy; for example, the study of tissue perfusion by ^{1}H imaging methods is particularly relevant to spectroscopic studies of energy metabolism. However, the extension of spectroscopy from a research technique to a routine clinical method is not straightforward, and the eventual role of clinical spectroscopy still remains to be evaluated.

Mackenzie Davidson Memorial Lecture

Technology assessment: prospects, approaches and costs

Barbara J. McNeil
Departments of Health Care Policy and Radiology, Harvard Medical School, Boston, Massachusetts, 02115, USA

This paper discusses alternative approaches to technology assessment in the USA and emphasizes a new approach supported by the National Cancer Institute. This approach is based on a "Radiology Diagnostic Oncology Group (RDOG)". The group consists of: (1) a central core working on design and analytical issues and (2) several participating institutions that submit to the core data and films on patients in any one of four protocols. This mechanism allows collection of about 200–250 cases per year in each protocol. Thus, preliminary, but statistically significant results are available within 12 months for many clinical questions. The paper discusses the organization of RDOG, preliminary results from one of its protocols (staging prostate cancer) and the costs to the government of using this approach to technology assessment. Mention is also made of several statistical issues that will need to be addressed if this type of technology assessment becomes more routine. This approach is contrasted with other approaches used in the USA, specifically: (1) data from single institutions, (2) meta-analyses and (3) consensus conferences. Finally, brief comments are made about the potential impact of new payment strategies in the USA (that is DRGs) on the diffusion of medical technologies and on the importance of technology assessment.

Contemporary Issues in Genito-urinary Radiology

Chairman: Prof. G. H. Whitehouse

Contrast agents and the kidney
P. Dawson
Radionuclide imaging of the urinary tract
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Interventional radiology in the age of lithotripsy
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Imaging in renal transplantation
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Post-natal assessment of ante-natally diagnosed hydronephrosis due to distal ureteric obstruction
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The treatment of calyceal diverticular stones
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Contrast agents and the kidney

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The pharmacokinetics and renal handling of urographic contrast agents are reviewed in order to clarify the factors dictating image quality in urography. The possible mechanisms underlying nephrotoxic manifestations of contrast agents are discussed in some detail and a hypothesis to explain clinical nephrotoxic events elaborated.

Radionuclide imaging of the urinary tract

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It is well established that radionuclide techniques can provide information about renal function which cannot be obtained by excretion urography, other radiographic techniques or ultrasound. In paediatrics, these are accepted as the best means of detecting pyelonephritic scarring and vesico-ureteric reflux. The prognostic significance of both reflux and scarring has been determined by long-term follow-up and comparison of children with and without reflux or scarring. There is good evidence that under the age of 5 years scintigraphic methods are more sensitive than ultrasound in detecting scarring. In those over 5 years, the two methods are complementary, although scintigraphy provides more useful information. There is as yet no ideal method for identifying patients with renal artery stenosis causing hypertension. Excretion urography has a low sensitivity, whilst angiography is impractical as a screening procedure, except in patients shown to be at high risk by other less invasive techniques. A number of radionuclide techniques have recently been described which claim to facilitate the clinical measurement of renal blood flow. The role of these in renal hypertension is compared with other established techniques. In patients with urinary obstruction or non-obstructing calculi, it is important to determine the relative contribution of each kidney to total function, and on follow-up to determine whether any change in relative function has occurred. In the patient presenting with chronic renal failure it is always important to assess whether function is symmetrically depressed or whether one kidney is making a major contribution. This has important consequences for the surgical management of such patients. This information can only be obtained non-invasively by the use of nuclear medicine techniques. Following renal transplantation, nuclear medicine techniques are the simplest methods of distinguishing the various causes of an acutely non-functioning transplant. These techniques are less useful in long-term follow-up of these patients.

Interventional radiology in the age of lithotripsy

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When extracorporeal shockwave lithotripsy (ESWL) became available in Germany some 5 years ago, it became clear that many renal calculi would be completely treated by this new method of stone disintegration. We were expecting that once this machine became more widely available, the need for other stone treatments such as percutaneous nephrolithotomy would become extinct. However, from the literature and from our own experience, it soon became clear that back-up facilities for percutaneous nephrolithotomy were a vital part in any unit performing shockwave lithotripsy. Because a unit has a lithotripter machine, the number and complexity of the calculi being treated increases enormously and it became clear that percutaneous nephrolithotomy had a complementary role to ESWL. Furthermore, a minority of stones could not be treated by shockwave lithotripsy because of variations in the intrarenal anatomy and drainage of the kidney. This paper summarizes the specific roles of ESWL and percutaneous nephrolithotomy and emphasizes which category of stone should be treated by ESWL and which should be treated by percutaneous nephrolithotomy. Percutaneous access to the kidney for endoscopic inspection of possible arterio-venous malformations or superficial tumours is also discussed. One of the main areas of difficulty in endoscopy is the ureter and problems related to ureteric obstruction are also covered. Lithotripsy is now being investigated for treatment of gallstones and a parallel is drawn between the methods available for renal stone treatment and gallstone treatment.

Imaging in renal transplantation

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Diagnostic radiology plays an important role in the management of the renal transplant patient. The traditional non-invasive methods of evaluating graft dysfunction use ultrasound and radionuclides. More recent developments include duplex Doppler and magnetic resonance imaging. Limitations and advantages of these techniques are discussed. Percutaneous interventional techniques are also outlined including arteriography, transplant artery angioplasty, percutaneous nephrostomy, ureteric dilatation and percutaneous stone removal.

The radiological investigation of the newer forms of urinary tract reconstruction

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Abstract not received.

Post-natal assessment of ante-natally diagnosed hydronephrosis due to distal ureteric obstruction

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The management of the heterogeneous group of conditions causing neonatal distal ureteric obstruction is, in many cases, empirical since the natural history is uncertain. The aim of this retrospective study was to determine which post-natal imaging techniques were most useful in planning management. Twenty patients referred to a regional neonatal surgical unit with ante-natal ultrasound (US) diagnosis of hydrnephrosis were reviewed. The age at referral was from 1 day to 2 months. Ante-natal ultrasound had detected hydro-ureter in one out of 20 cases. Post-natal ultrasound had detected hydro-ureter in 10 out of 17 cases (59%). There was good correlation between the degree of urinary tract dilatation and the subsequent diagnosis of obstruction. Nineteen out of 20 had intravenous urography; five of these had antegrade studies. In 13 out of 15 cases with moderate or severe hydro-ureter, the correct level of obstruction and a specific diagnosis was made from these studies. In the four cases with minimal dilatation, no definite diagnosis was made but none were subsequently found to be obstructed. Fifteen patients had cystograms; two were abnormal, one showed vesico-ureteric reflux, the other posterior urethral valves. All patients had diuresis renography; three had normal curves, eight had obstructed curves and nine had equivocal curves. Surgery was performed in 12 patients, of which seven had a diagnosis of non-obstructed, non-refluxing mega-ureter and one patient was normal. Our conclusions are that no single imaging technique allows full evaluation of these patients. The intravenous urogram, where necessary supplemented by antegrade pyelography, is the most helpful investigation. The main benefit of ante-natal ultrasound diagnosis is that it allows early post-natal assessment of asymptomatic infants.

Congenital urethral diverticula in paediatric practice: modes of presentation and the spectrum of radiological appearance

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Diverticula of the anterior and posterior male urethra are unusual findings at micturating cystourethrography. Ten cases presenting over a 5-year period to a regional paediatric urological unit are described, illustrated and their modes of presentation compared with radiographic appearances. Posterior and anterior diverticula occurred with equal frequency. Posterior diverticula are associated with other congenital anomalies yet anterior diverticula occur as a primary isolated finding. Wide-necked anterior urethral diverticula present in infancy with urinary obstruction and retention. We describe three such cases presenting with infection and post-micturition dribbling which required symptomatic treatment only. They must be differentiated from the diverticulum of the fossa navicularis with a specific clinical and radiological picture requiring specific treatment. Diverticula of the anterior urethra should not be confused with the scaphoid form of megalourethra which produces similar urethrographic appearances. The radiological appearances and necessity for correct technique at micturating cystourethrography are highlighted.

The treatment of calyceal diverticular stones

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Calyceal diverticula often harbour stones. These are usually symptomatic and require treatment. The days of open surgery are gone. Extracorporeal shockwave lithotripsy will fragment the stones, but the narrow neck that forms the communication between diverticulum and calyx is too narrow to allow stone fragments to pass. The aims of treatment are to remove the stones and obliterate the diverticulum. In a series of six patients, this has been done with a percutaneous nephrolithotomy approach. The diverticulum is punctured directly and a 28 French tract established. The stones are removed and the neck of the diverticulum coagulated with diathermy. Follow-up in all six patients was with a limited excretory urogram. In all six, there was no evidence of the calyceal diverticulum or of residual stones. This approach fulfils the aims of treatment.

Acquired cystic disease in the native kidneys of dialysis patients and renal transplant recipients: an ultrasound study

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Acquired cystic disease (ACD) occurs commonly in the kidneys of patients with end-stage renal failure. Reports that the disease is associated with hypernephroma and that it regresses following transplantation prompted us to examine the native kidneys of our renal failure patients using high-resolution ultrasound scanning. Patients receiving either continuous ambulatory peritoneal dialysis or haemodialysis were studied as well as renal transplant recipients. All patients were scanned by experienced ultrasonographers using an Acuson 128 ultrasound machine. Patients with adult polycystic disease or bilateral nephrectomy were excluded from the study. A total of 67 patients with functioning transplants and 43 patients receiving dialysis were examined. Sixty-three patients with transplants and 41 patients receiving dialysis had at least one kidney imaged (16 kidneys were not seen for technical reasons and seven were absent). In patients who had at least one kidney imaged, 78% in the transplant group and 87% in the dialysis group had detectable cysts. Neither the duration nor type of dialysis had any effect on the incidence or severity of ACD. Within 1 year of transplantation, the incidence of detectable cysts was 93%, declining to 73% in patients who had a functioning graft for more than 2 years. The percentage of patients who had more than 10 cysts detected showed a similar trend. No renal tumours were detected in either group. The study demonstrates the ability of high-resolution ultrasound to detect the small scarred kidneys of renal failure patients (92% of kidneys present were detected). It adds further support to the view that ACD tends to regress following successful transplantation, the effect being appreciable at 2 years.

Staging of renal tumours by computed tomography: a new technique using femoral vein contrast infusion and single-location dynamic scanning

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A new dynamic computed tomographic technique for the staging of renal tumours is described. The technique was developed to improve the detection of tumour involvement of the inferior vena cava (IVC) and renal veins as previous techniques have been less sensitive in demonstrating involvement of these structures than for nodal involvement or extracapsular spread. The technique comprises three stages. (1) A series of plain scans were performed to locate the level of the renal veins. (2) A single location dynamic sequence was performed at the level of the renal veins. Seven scans were performed within 1 min after the injection of a 50 ml bolus of intravenous contrast medium. The images demonstrated the flow of contrast medium through the renal veins and into the IVC and time–density curves were constructed which demonstrated the flow graphically. (3) The femoral vein was then cannulated and 100 ml of intravenous contrast medium infused whilst scans were performed at levels throughout the abdomen to demonstrate the IVC. Thrombus within the vessels is seen either as a filling defect within the vessels or as reduced flow as demonstrated by the time–density curves. Arterialized thrombus may be demonstrated as enhancement within the vein during the arterial phase of the dynamic sequence. Initial studies involving 10 patients are promising and have shown the technique to be very accurate when compared with the results of pathological staging, with nine patients accurately staged and one overstaged where involvement of the renal vein was falsely diagnosed. Further assessment of the technique is underway.

The radiology of urinary diversion

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Urinary diversions are performed for the treatment of bladder and cervical cancer, interstitial, radiation and chemical cystitis and for functional bladder disorders. Follow-up of these patients is directed at the diversion itself and the upper tracts. The majority of cases are assessed by retrograde loopography. Sixty-one consecutive patients are presented. The types of diversion were as follows: ileal conduit (56), ureterosigmoidostomy (2) and single cases of cutaneous ureterostomy, rectal bladder and Metrofanoff pouch. The primary pathology was bladder carcinoma (22), unstable or neurogenic bladder (20) carcinoma of the cervix (7), interstitial cystitis (5), ectopic vesicae (2), chemical cystitis (1), Crohn's fistula (1) and three unknown cases. Loopography demonstrated normal appearances in 48 patients. The 13 abnormal cases were due to enteric strictures (4), ureteric anastomatic strictures (3), leaking conduits (2), recurrent renal transitional cell tumour (2) and a calculus within the conduit of one patient. The patient with the cutaneous ureterostomy developed a ureteric stricture. Reflux into the upper tracts occurred in all patients, permitting anatomical detail. Following urinary diversion, loopography is the technique used to establish the anatomy of both the diversion itself and the integrity of the upper tracts. Excretory urography is rarely required. This paper discusses the procedure itself, the findings in 61 patients and the limitations of loopography, especially related to upper tract obstruction.

Videocystometrography after augmentation cystoplasty

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Videocystometrography (VCMG) has enabled clinicians to diagnose detrusor overactivity (hyper-reflexia or instability) and hypocompliant bladders. Such conditions may lead to frequency of micturition, urgency and urge incontinence. It is current practice to perform augmentation cystoplasty when drug therapy fails in such cases. Similar procedures may also be performed after subtotal cystectomy for bladder carcinoma, tuberculous cystitis, post-irradiation cystitis and interstitial cystitis (IC). The operation chosen depends on the potential bladder capacity; if small, colo-, caeco- or ileo-caecocystoplasty are indicated, if large, "clam" ileo-cystoplasty is preferable. We have performed VCMGs in 12 patients with symptoms of urinary frequency and urgency who have previously undergone "clam" ileo-cystoplasty ($n = 5$), caeco-cystoplasty ($n = 6$) and colo-cystoplasty ($n = 1$). The indication for bladder augmentation was IC ($n = 3$), post-traumatic fibrotic bladder contraction ($n = 3$), idiopathic detrusor instability ($n = 4$) and post-irradiation ($n = 2$). The mean neo-bladder capacity after caeco-cystoplasty was 511 ± 71.4 ml and was less after "clam" ileo-cystoplasty (358 ± 87.2 ml). The mean maximum filling pressure within the caeco-cystoplasties was 60.0 ± 6.85 cm water and pressure rises coincided with peristaltic contractions within the colonic segment. Within "clam" ileo-cystoplasties, pressures were similar (mean 56.8 ± 11.0 cm water) but without peristaltic contractions. In spite of high pressure, unilateral ureteric reflux was present in only one caeco-cystoplasty and two "clam" ileo-cystoplasty cases, whilst the colo-cystoplasty case had high-pressure bilateral reflux. Urinary frequency and urgency following colo- or caeco-cystoplasty is due to high-pressure peristaltic waves and these may be associated with ureteric reflux. This usually responds to anticholinergic therapy but can be prevented by detubularization of the colonic segment or uretero-ileo-caecocystoplasty, which relies upon the anti-reflux property of the ileo-caecal valve. Urinary freequency following "clam" cystoplasty is due to inadequate augmentation or irritative symptoms from the natural bladder. Videocystometrography is vital in the assessment of these problems.

The ultrasound cystodynamogram: its use in voiding disorders

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The degree of bladder outflow obstruction may be assessed by the intravenous urodynamogram (IVUD) or in more detail by videocystometrography (VCMG); however, VCMG requires bladder catheterization and voiding in public, which often leads to inhibition of sphincter relaxation. For this reason the urinary "free" flow rate performed in private is more representative of the true voiding pattern. The ultrasound cystodynamogram (USCD) evaluates the bladder capacity, mean and maximum flow rate using a standard flow meter, flow pattern and the post-micturition residual. We have assessed the diagnostic capability of USCD in 78 consecutive cases, 27 of whom have also had VCMG. These 78 cases were post-prostatectomy assessments ($n = 18$), post-colposuspension ($n = 7$), post-urethral dilatation ($n = 11$), long-term detrusor failure ($n = 12$), failure of urethral sphincter relaxation ($n = 12$), detrusor-sphincter dyssynergia ($n = 5$), urethral reconstruction ($n = 4$) and other voiding disorders ($n = 9$). Comparison of data obtained using both techniques revealed no significant difference at the 5% level (Mann Whitney and two-sample t-tests). We have found USCD to be accurate, safe and reproducible. It is inexpensive since it utilizes equipment available in all imaging departments. The ultrasound cystodynamogram has proved to be most helpful in the follow-up of post-operative patients, *e.g.* after surgical relief of obstruction and post-colposuspension, as it is a convenient way of recording changes in voiding efficiency. It is a useful adjunct to VCMG since it is non-invasive, well tolerated by patients and is easy to perform at regular intervals. The results discussed here suggest that USCD and VCMG provide comparable data during routine investigation, whilst VCMG remains the "gold standard" for more complex cases.

Microwave testicular thermography: assessment of scrotal temperature profiles in male infertility

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A new method of testicular thermography using a microwave detector is presented, its use described and initial results reported. The equipment comprises a temperature probe, similar in appearance and use to an ultrasound probe. The probe detects microwave emissions from a block of tissue 1 cm in diameter and 2 cm deep to the probe surface. The recorded temperature appears on a digital display and a chart recorder with temperature plotted against a time axis. The probe is moved along the skin surface in 1 cm steps at even time intervals, starting above the inguinal ligament, passing down the scrotal neck and finishing at the lower testicular pole. The equipment has advantages over other thermographic devices in that it measures core temperature, is robust in design, does not require repeated calibration and can be used in an unstable room temperature. Forty cases attending the male infertility clinic were assessed. The scrotal temperature profiles of normal testes, atrophic testes and varicoceles are demonstrated. There were 16 clinical varicoceles in this group of patients. In seven of these an abnormal flat temperature profile across the scrotum was shown with an abdominal/testicular temperature difference of less than 0.4°C. It is believed that this is a simple and accurate thermographic technique that is quick to perform and can be used in conjunction with clinical or ultrasound examination of the scrotum.

Risk Estimates in Diagnosis and Therapy

Chairmen: Profs E. Rhys Davies and C. A. Joslin

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Risk estimation in diagnosis and therapy

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The medical value of ionizing radiation was appreciated almost immediately after the discovery of X rays by Röntgen. The first damaging effects to be recorded were skin cancers and these were identified within a decade of the discovery of X rays. For many years the medical uses of ionizing radiation were the major contribution to the population burden from artificial radiation. The arrival of other artificial sources has coincided with major advances in instrumentation and technology, which have tended collectively to increase this radiation burden. Now the annual incidence of diagnostic X-ray investigation is over 0.5 per head, and the equivalent of some 90% of hospital inpatients receive a diagnostic X-ray examination. Thus, it is even more important to heed the recommendation of the International Commission on Radiological Protection that "every procedure involving radiation exposure is 'justified', in the sense that the benefits to be expected from it outweigh the detriment, including any component of radiation injury, that may result from it." Implicit in this recommendation is the need to estimate risk in both diagnosis and therapy. The purpose of this paper is to explore the philosophy, extent and implications of such risks. The extended target of such discussions is to identify where the needs lie for developing strategies to change and improve the medical uses of ionizing radiations.

The role of risk assessments

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Estimating the risks involved in any medical procedure forms one part of the process of confirming that these risks are less than those which are prevented by using the procedure. In the great majority of cases, any such comparison appears unnecessary, since the benefits of conventional clinical methods—in radiological diagnosis and therapy, as in surgery and in the use of familiar drugs—seem to be substantial as compared with any small risks involved. A review of the risks of cancer induction in radiodiagnosis and in radiotherapy is valuable, however, for a number of reasons. One obvious importance lies in confirming that the risks involved in all such procedures are in fact less than the risks avoided by their use. Our preoccupation with radiation risk assessment is not often linked with the necessary parallel evaluation of the risks avoided—and with their evaluation in terms which allow numerical comparison with the radiological risks—for example, by comparing the total average periods of life expectancy lost or of healthy life impaired under each alternative. Such comparisons have been well addressed in considering the nett benefit at different ages in screening for breast cancer, and earlier, in Japan for stomach cancer. All such uses of risk assessment are potentially important in offering perspectives on the levels of safety of radiological procedures, both in relation to alternative methods of diagnosis or of treatment, and also by comparison with other normal hazards of life which may be more familiar to the patient and to the public. But it is necessary that the average likelihood of benefit, experienced in those patients in whom radiography is informative or the therapy is successful, be reviewed alongside the equally probabilistic assessment of the radiation risks incurred.

Recent changes in estimates of radiation risk and implications for dose limits

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The publication of the 1988 report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) represents a major step forward in the estimation of the levels of risk associated with exposure to ionizing radiation. Data are now available which quantify the effects of high doses received at high dose-rates in a number of organs and tissues as well as the whole body. The estimates of risk given by UNSCEAR for fatal cancers are up to four times higher than when the Committee last reported in 1977. The main reasons for this change are firstly, the change in dosimetry of the Japanese survivors of the atomic bombing and secondly, the increased epidemiological follow-up period, to 1985, which tends to confirm the relative risk model. Uncertainties exist, however, in the numbers of cancers which will arise in irradiated populations that are still alive, and in the extrapolation to low-dose, low-dose-rate risk factors. Since, in radiological protection, the assumption is made of a linear relationship between dose and risk, it follows that in setting dose limits it is necessary to consider not only the risk per unit dose, but also the limit of tolerable or acceptable risk. In this paper, the question of the limitation of risk is addressed for both members of the public and those occupationally exposed. The same question is being addressed by the International Commission on Radiological Protection (ICRP) in the formulation of their new recommendations. The relationships between dose and risk can be used to speculate on the range of dose levels within which ICRP may set limits. Finally, it is emphasized that, because all exposures will be as low as reasonably achievable, actual doses received would be expected to be below the limits derived in the paper.

Risk of cancer induction in radiodiagnosis

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Risk estimates currently accepted for cancer induction are related to the sex of the persons exposed as well as to their age. Patients presenting for radiodiagnosis in hospital span both sexes and the complete age range of the population. To estimate the overall risk of cancer induction from radiodiagnosis, it is necessary to know the number and type of examinations conducted, the typical spread of radiation doses and the age and sex of those exposed. It is important to remember that cancers need not be fatal and the distinction between fatal and non-fatal cancer risk is discussed. On an individual patient basis, the risk can be estimated more specifically and is likely to lie between 1 in 2 000 000 and 1 in 1000. Even high-risk procedures are acceptable to the patient if they know there is a net benefit to themselves as individuals. In the view of the diagnostician, these risks are often felt to be negligible in relation to the overall risks of certain diagnostic procedures. A compilation of the usual range of radiation doses with their risk estimates for radiodiagnostic procedures are presented, together with a comparison of other associated hospital-based risks.

Risk of cancer induction in radiotherapy

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Whilst the aim of radiotherapy is to irradiate the tissue in the target volume to a tumoricidal dose, it is also essential to minimize the effects of irradiation to other tissues, thereby avoiding unnecessary normal-tissue reaction and reducing the risk of inducing a secondary primary tumour. Normal tissues in patients undergoing radiotherapy are unavoidably subjected to scattered radiation produced within the treatment volume and to leakage radiation from the head of the machine. These sources of radiation contribute to the increase in risk of cancer induction in later life. Using published data on the risk of induction of cancer in patients who have received therapeutic doses of ionizing radiation to limited areas, a review is undertaken of the risk of cancer induction associated with various treatment techniques and how these can be minimized by effective treatment planning.

Medicolegal aspects of medical radiation exposure

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The main matters raised for discussion are as follows. (1) Although interest has been concentrated on the possibility of carcinogenesis, there is now increasing concern about scarring and psychological effects. (2) Possible mechanisms of radiation carcinogenesis and the concept of a doubling dose. (3) The need for evidence of exposure, and its amount, together with subsequent damage. (4) Evidence of negligence needed in most instances, though not in the nuclear industry. (5) Level of proof required: "on the balance of probabilities". (6) Consent: informed consent, mentioning all risks; the body of opinion regarding reasonability of the procedure undertaken; and the large and growing number of "cases" relating to radiology (non-radiation problems concerning interventional techniques are excluded).

Risk and dose limits: the impact on occupationally exposed persons

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The basic premise of radiological protection in the nuclear industry is the total avoidance of non-stochastic radiation injury. Avoiding overt unmistakable occupational injury is only an extension of good practice in conventional non-radiological safety. A perception, both workforce and public, of the major hazard to workers in the nuclear industry is of stochastic injury, *i.e.* subsequent development of malignant disease. However, significant excesses of cancers have not been seen as yet in British nuclear workforces, indeed at present they show a lower cancer risk than the general public. This is, from the industry's point of view, radiation exposure at occupational dose levels representing a computative risk which, while it cannot be ignored, has not yet been demonstrated to be real. Although a modern nuclear plant has been designed to operate at dose levels to workers (and to the general public) far below current or projected dose limits, plants which were designed 30 or more years ago, are still in use and still have considerable economic life. The specific problems leading to high individual worker doses in the nuclear fuel cycle and in the early generation of magnox reactors are described and the individual and collective doses which result from these within the nuclear industry are discussed. We cannot walk away from history, and the decommissioning and post-operative clean-out of old plant will require further worker exposure. Dose limits which are unduly restrictive actually increase collective worker dose. There has been a steady downward trend in individual doses to workers in the nuclear industry for more than a decade, and the collective dose has declined more slowly. Occupational radiation doses to other industrial groups are compared. It is ironic that the highest individual worker doses in the UK are to non-coal miners while the largest collective radiation dose to occupationally exposed persons is in the mining of coal, not the nuclear industry!

Mammography: proffered papers and posters

Chairman: Dr D. Asbury

The quest for accuracy, consistency and uniformity of performance in mammographic screening: the systematic imperative
A. G. Gale, G. E. Walker, E. J. Roebuck and B. S. Worthington
Information technology in breast cancer screening
R. N. Priestland, A. G. Gale, S. J. Roebuck and B. S. Worthington
Automatic detection of microcalcifications in digital mammograms
D. H. Davies, D. R. Dance and C. H. Jones
X-ray protection considerations for mammography screening centres
A. Walker and A. R. Hounsell
A review of breast carcinomas missed by mammography
M. G. Wallis, M. T. Walsh and J. R. Lee
Mammographic localization of impalpable breast lesions: setting up a service
C. Clout and M. C. Collins
Breast ductography: its role in the diagnosis of breast disease
A. W. Reid, N. J. McKellar and G. R. Sutherland
The role of computed tomography in the investigation of recurrent axillary disease in patients with carcinoma of the breast
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The radiological features of cystosarcoma phylloides with clinical pathological correlation
J. E. Page and J. E. Williams

The quest for accuracy, consistency and uniformity of performance in mammographic screening: the systematic imperative

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The objective of systematic training of observers for breast screening is to achieve both a uniformity and accuracy in the identification of relevant features with a high consistency over time. When an observer examined a series of mammograms for the presence of 41 radiological features on two separate occasions, fewer than 5% of cases showed an important change in the features reported. In contrast, however, when a group of experienced radiologists independently assessed a series of mammograms for the same features, complete concordance of reported features was found in only 3.3% of cases. Furthermore in a simulated breast screening situation we found, on ROC analysis, that experienced mammographers achieved similar sensitivity scores whilst differing in the features reported in individual mammograms. Even allowing for the problem of unambiguously codifying image descriptors we conclude that these data indicate a differing repertoire of schemata brought to the identification task by each observer. This is an important factor to be considered both in design of training programmes and in any expert systems approach to radiological diagnosis.

Information technology in breast cancer screening

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Radiograph reporting in breast cancer screening is typically made using multiviewers with each woman's data eventually being entered onto a computer system. Whilst both of these advances improve the efficiency of the overall reporting process, the question remains of whether a technique can be employed to speed up the data encryption process without sacrificing accuracy. This paper details the investigation for an appropriate information technology solution to this problem. The current reporting approach adopted locally in breast screening is that each woman's mammograms are examined by radiologists who log information concerning both the woman's identity and radiological appearance on paper for subsequent transcription onto a computer system. Different human–computer interfacing methods were investigated resulting in the development of a bar code input device which mimics the current data recording process. This allows rapid identification of a woman's mammograms and produces faster computer input of data whilst maintaining high operator acceptability. An evaluation study was then undertaken where experienced observers reported on 100 women's mammograms, on two separate occasions, using both the existing technique and the bar coding system. The results of this evaluation are detailed and the potential of the system highlighted.

Automatic detection of microcalcifications in digital mammograms

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The automatic detection of clusters of microcalcifications in digital mammograms has been investigated using a combination of local area thresholding and texture analysis. Conventional screen–film mammograms (selected by the authors and a radiologist from a training library of mammograms) were digitized using a Joyce-Loebl scanning microdensitometer with a pixel size of 0.1 mm × 0.1 mm. The images were processed on a SUN 3/60G workstation. Segmentation of microcalcifications from the background of normal breast tissue in any given mammogram was accomplished using a local area thresholding method. This technique partitions the regions of the breast within the mammogram into smaller sub-images and determines using a point dependent method a threshold for each of the sub-images. Each sub-image is then classified as having normal or abnormal texture using a region dependent method. Only structures segmented in sub-images containing abnormal texture are retained. Large structures and noise are eliminated by placing upper and lower limits on the size of the detected signal. Finally, a clustering principle is imposed to select significant clusters of microcalcifications. The performance of the algorithm has been assessed using a set of 25 mammograms. Preliminary results indicate an improvement over both the true positive and false negative detection rates achieved by the algorithms published by previous workers.

X-ray protection considerations for mammography screening centres

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The inception of the National Breast Screening programme, following publication of the report of a working group under the chairmanship of Sir Patrick Forrest, led to the construction of a significant number of new mammography rooms, including mobile units, with many more being proposed for the next few years. As a result, radiation protection advisers are now being required to give advice on room construction for these units. They will need access to both attenuation data and scatter measurements on which to base their recommendations. This poster presents measurements carried out at mammographic energies of the attenuation properties of a range of materials which could be used in barrier construction. Measurements of the amount of scatter from a BR12 phantom are also presented. In addition, the application of these results to the situations which will be found in the new screening centres and mobile units is discussed and measurements performed to confirm the conclusions are presented.

A review of breast carcinomas missed by mammography

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Mammography is a sensitive and specific technique in the diagnosis of breast cancer; however, some tumours are missed by this investigation. The false negative rate for mammography reported in the literature varies widely from 4% to over 30%. The mammograms performed in a symptomatic population at the The General Hospital, Birmingham between 1980 and 1987 were retrospectively analysed. False negative mammograms were identified by cross referencing the pathology records with the mammogram reports. A total of 788 cancers were identified. Of these, 72 were initially missed on mammography giving an overall false negative rate of 9.1%. This rate varied over time and is now running at 4.8%. This improvement coincided with the introduction of a grid and radiographer training. The radiographs of 69 patients were available for subsequent review. In 49% no abnormality was seen (7% due to poor radiographic technique, 19% due to dense breasts and the remaining 23% were considered to have normal mammographic appearances). Observer error was responsible in 29%. In 16% an abnormality was seen but there were no radiological criteria of malignancy. Of the remaining 6% (four cases), two lesions at previous biopsy sites were misinterpreted as scarring. In this study 36% of cases were considered to be due to avoidable error. The remaining 64% were uncorrectable giving an inevitable false negative rate of 6%. The principal reasons for this were normal mammographic appearances, dense breasts and benign appearing lesions. Comparison with other published series is discussed.

Mammographic localization of impalpable breast lesions: setting up a service

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A quick, simple, accurate method of localizing lesions detectable by mammography alone will be essential to the development of any breast screening centre. Over the past 2 years we have been developing a localization service in Sheffield. A critical review of the first 50 cases has been undertaken. The mammographic indications, accuracy and complications of each localization have been analysed. We have determined the overall incidence and age distribution of carcinoma. We present the results of the review and describe some of the difficulties experienced in setting up the service.

Breast ductography: its role in the diagnosis of breast disease

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Mammography is a sensitive and specific method for detecting parenchymal breast pathology, but is inadequate for the investigation of nipple discharge. Contrast mammography, or breast ductography, is a relatively innocuous method to determine the nature, location and extent of lesions causing nipple discharge. A series of 60 breast ductograms is reported to demonstrate the role of ductography in the radiographic diagnosis of breast disease. Excision biopsy was subsequently performed in 15 patients for intraduct papilloma, intraduct carcinoma and blocked main ducts. Three patients with blocked ducts were being observed, their discharges having ceased. All these patients presented with either a serous or a bloody discharge. Of the remaining 42 patients, ductography demonstrated 18 cases of duct ectasia, 12 with a green discharge and six with a serous discharge. Two other patients with a serous discharge were shown to have fibrocystic disease affecting the ducts. In this series, ductography confirmed that no patient with a green discharge required surgical intervention. Although ductography is a safe procedure with no lasting complications, dilatation of the duct orifice can be uncomfortable. If ductography were limited to patients with a serous or bloody discharge from a single duct orifice, no lesion requiring surgery would be missed. This would safely reduce the number of examinations by 20%, avoiding minor discomfort to the patient and unnecessary radiation exposure. This protocol would also include ductograms on patients with simple breast disease who do not require surgical intervention. This too is important to the clinician and reassuring to the patient.

The role of computed tomography in the investigation of recurrent axillary disease in patients with carcinoma of the breast

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Thirty-five patients with clinically suspected axillary recurrence from carcinoma of the breast were investigated using computed tomography (CT). Dynamic incremental scans of the axillae were obtained during the infusion of intravenous contrast medium and compared with the clinical findings and follow-up (2–268 days, mean 179 days). Nine patients were found to have recurrent axillary disease by CT. Eight of these had been clinically palpable before CT examination. In the remaining patient, previous radiotherapy had made clinical examination of the axillae difficult. In two patients, clinical examination suggested the diagnosis of axillary vein thrombosis and this was confirmed by CT. Fourteen patients had normal axillae on CT. Of these, one patient was shown to have a destructive lesion at T1 and had had T1 motor and sensory signs clinically. Another patient was shown to have pulmonary metastases which were not clinically appreciated. In one patient with normal CT, small nodes were palpable which had positive cytology. In conclusion, CT of the axillae in patients with suspected recurrent disease does not offer any advantage over clinical palpation unless the axillae are difficult to examine because of previous radiotherapy. As in other sites, CT is unable to detect pathological nodes unless they are enlarged. It can, however, be used to confirm axillary vein thrombosis and is also useful in radiotherapy planning.

Magnetic resonance imaging of the breast in the assessment of suspected recurrent breast carcinoma

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Experience with magnetic resonance imaging of the breast remains limited. Studies to date have shown that differentiation between carcinoma, proliferative dysplasia and certain benign breast diseases can be difficult. The problem of suspected recurrent disease in patients with treated breast carcinoma is considered. More than 60 consecutive cases were studied, all previously treated by lumpectomy combined with radiotherapy, chemotherapy or both. Recurrence was suspected either clinically by a palpable mass, breast pain or nipple discharge or radiologically following X-ray mammography. In the majority of cases the principal differential diagnosis rested between recurrent tumour or post-treatment fibrosis. T_1- and T_2-weighted images were performed in the axial and sagittal planes using a 1.5 T superconducting system. A general-purpose surface coil with a purpose-built coil holder was used for imaging the breast. The tomographic format, inherent high soft-tissue contrast and tissue characterization properties allowed an accurate diagnosis in the majority of cases. The morphological appearances of recurrent tumour, post-radiation fibrosis and other post-treatment effects are described and contrasted. In those cases where differentiation on morphological grounds alone was difficult, the pattern of gadolinium-DTPA enhancement proved most helpful. It is believed that magnetic resonance imaging has an important role to play in the evaluation of patients undergoing treatment for breast cancer.

The radiological features of cystosarcoma phylloides with clinical pathological correlation

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Cystosarcoma phylloides is a rare tumour of breast tissue accounting for approximately 1–2% of breast masses. The tumour encompasses a broad spectrum of disease from benign to frankly sarcomatous. The radiographs of 10 patients with histologically proven cystosarcoma phylloides are reviewed with particular reference to site and radiographic morphology of the tumour and the effect on the surrounding breast stroma. The results are correlated with the clinical and histological findings in each case. All 10 patients were between the ages of 30 and 55 years at presentation. The tumour ranged in size from 1 cm diameter to a massive lesion occupying the entire breast. Most were well defined with either smooth or lobulated margins and caused compression of the adjacent breast stroma producing a clear "halo" around the tumour. Atypical features included calcification, increased vascularity and poorly defined margins. Most tumours were histologically benign, requiring lumpectomy only. In one case, radical mastectomy was performed and in one patient the tumour recurred following local excision. The significance of these findings is discussed with reference to both diagnosis and management.

Face and Neck: proffered papers and posters

Chairman: Dr J. K. Davidson

The role of dacryocystography in the management of epiphora
J. Nixon and J. Virjee
Comparison of Lipiodol and Urografin 290 in sialography
D. A. Nicholson and I. Zammit-Maempl
Paranasal sinuses: are three views necessary?
J. I. S. Rees, K. Lyons, M. Hayward and W. Ennis
Magnetic resonance imaging of the temporomandibular joint: should it replace arthrography?
M. H. Morse and W. D. Jeans
Computed tomography in the localization of parathyroid tumours
P. Mayor, J. E. Adams, P. H. Adams and M. Davies
Oesophageal insufflation testing: clinical implications
P. M. Sloane, J. F. Griffin and T. P. O'Dwyer
Conventional versus computed tomography in patients with laryngeal tumours
M. Bernard, A. Whyte and C. Hayward

The role of dacryocystography in the management of epiphora

J. Nixon and J. Virjee
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Epiphora is a common but rarely serious condition in ophthalmological practice, which is frequently caused by abnormalities of the lacrimal drainage system. A retrospective study was carried out on the medical records of 114 patients who had undergone dacryocystography for epiphora, with the objective of assessing the role of dacryocystography in the management of patients with epiphora. It was found that 18 patients who were offered surgery after dacryocystography refused it or were assessed as unfit for surgery, thus demonstrating the need for careful assessment and counselling of patients prior to subjecting them to investigation. The proportion of patients who went on to have lacrimal surgery was significantly higher ($p < 0.001$) in the group who had dacryocystograms showing obstruction (48.5% had surgery) than in the group whose dacryocystograms were normal (7.6% had surgery). However, when the patients with obstruction shown by dacryocystography were grouped according to the level of obstruction, it was found that there was no significant difference in the proportion of patients undergoing lacrimal surgery between these groups. It was also found that the surgical technique used did not depend on the level of obstruction. These findings suggest that the anatomical information furnished by dacryocystography is not necessary for the management of epiphora, and that an investigation which simply demonstrates the presence of obstruction may be adequate. The result of syringing carried out in ophthalmology outpatients was compared to the outcome of dacryocystography, and the two were found to correlate poorly. Despite this, 86.5% of those who had patent systems on syringing went on to have normal dacryocystography. Considering the non-serious nature of this complaint this level of specificity may be considered acceptable, in which case patients with systems that are patent to syringing should not be investigated further with dacryocystography.

Comparison of Lipiodol and Urografin 290 in sialography

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Sialography using Lipiodol ultra fluid (UF) is still a widely used radiological technique. Many other different contrast media have been used, the three main criteria of choice being quality of examination, clinical tolerance and cost. A prospective study was conducted to compare the clinical tolerance and diagnostic quality of Lipiodol UF with Urografin 290. Urografin 290 was chosen because of its availability in 20 ml vials and cost. Forty patients, age 17–64 years, were randomly allocated to the two media. Standard preliminary AP and lateral-oblique radiographs were taken, with occlusal views where appropriate. A metal cannula with an olive tip was inserted into the duct orifice and contrast was injected until the patient indicated discomfort in the region of the gland. The cannula was left in place whilst repeat radiographs of the filled duct system were taken. The commonest presenting symptom was unilateral swelling (56%), followed by bilateral swelling (24%). Other indications included local pain and a dry mouth. Patients' symptoms before, immediately after and at 24 h were recorded. Radiographic quality was independently assessed on a three-point scale. In all patients sialography was successful. Significantly more side-effects were experienced after Lipiodol. In particular, 75% of patients complained of swelling, and 70% of pain. Comparative figures in the Urografin group were 30% and 35%, respectively. Other side-effects of altered taste and nausea were also more frequent in the Lipiodol group. No significant differences were found in the radiographic quality of the contrast sialograms in the two groups. We suggest the use of Urografin 290 as the contrast medium of choice, because of its satisfactory filling of the ducts, its improved clinical tolerance, and lesser cost.

Paranasal sinuses: are three views necessary?

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Conventional teaching recommends the use of three projections in the routine radiographic assessment of adult paranasal sinuses: the occipitomental (OM), occipitofrontal (OF) and lateral views. It is current practice to employ all three projections in many centres. We have assessed the value of the OM radiograph alone compared with all three views in the evaluation of the paranasal sinuses. The three projections of 100 consecutive adult patients presenting to the radiology department were reviewed. No trauma patients were included. The radiographs were reported in two separate studies. The OM radiographs alone were reported initially, and at a later date the three views were reported together. The results showed a good correlation between the two studies, the same diagnosis being achieved by two independent observers in 98% and 99% of cases, respectively. In conclusion, the OM view is sufficient for diagnostic purposes in the majority of patients with diseases of the paranasal sinuses. Additional OF views may occasionally be required in pansinusitis if the frontal sinuses cannot be adequately viewed on the OM. However, meticulous radiographic technique is essential. The lateral view contributed no additional information. Limiting the projections routinely used to the OM view will result in a 55% reduction in the radiation dose to the patient and a substantial saving in film costs.

Magnetic resonance imaging of the temporomandibular joint: should it replace arthrography?

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Videoarthrography has, for some years, been the radiological investigation of choice when considering surgical investigation in the treatment of temporomandibular joint pain-dysfunction syndrome. This investigation is, however, invasive and somewhat uncomfortable; additionally, for those not undertaking the investigation on a regular basis, it may pose problems both in performance and in interpretation. Some clinicians and radiologists have, accordingly, been reluctant to use arthrography, but have welcomed the increasing availability of magnetic resonance imaging as an alternative diagnostic tool. We review our experience with both imaging modalities, with particular reference to diagnostic yield, complications, costs and convenience, and consider the development of quasi-cine loop imaging. We conclude that magnetic resonance imaging may well be the investigation of choice when clinical evidence suggests the presence of an irreducible anteriorly subluxated articular disc, but that arthrography offers an, as yet, unrivalled view of disc dynamics, and should continue to be an important investigation in patients with intermittent or variable symptoms.

Computed tomography in the localization of parathyroid tumours

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Several imaging techniques have been applied to the pre-operative localization of parathyroid tumours. The introduction of general purpose computed tomographic (CT) scanners offered theoretical potential as a non-invasive method of localization, but initial studies proved disappointing, with only large tumours being identified. Developments in CT technology have resulted in improved spatial resolution and faster scanning capability, allowing better delineation of anatomical structures in the neck with contrast enhancement. The study was undertaken to reappraise the role of CT in the localization of parathyroid tumours. Sixty-six patients with surgically proven primary hyperparathyroidism were examined over a 4-year period (1983–1987). Scans were performed on a GE 8800 scanner for the initial 2 years, and subsequently on a GE 9800 scanner. Forty-eight (73%) tumours were correctly localized. Thin sections and the use of intravenous contrast medium improved the ability to detect tumours, and the measurement of CT attenuation values proved useful in differentiating parathyroid from thyroid tissue. Computed tomography failed to correctly localize the parathyroid tumour in 18 (27%) patients. In some of these patients, coincidental thyroid abnormalities, which occur with increased frequency in primary hyperparathyroidism, made interpretation of the scans difficult or incorrect. With improved scanner technology and experience, CT offers a reliable and non-invasive method for the pre-operative localization of parathyroid tumours.

Oesophageal insufflation testing: clinical implications

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Laryngectomized patients vary in their capacity to acquire a functional level of oesophageal speech. Anatomical and physiological abnormalities in the reconstructed pharynx significantly contribute to this variance. This study has shown that oesophageal insufflation testing under standard videofluoroscopy provides information that: (a) is diagnostically significant in assessing the potential for oesophageal speech acquisition, (b) identifies the causes of failure and (c) indicates the correct form of surgical intervention. A series of 50 laryngectomized patients were assessed using the above technique. Patients with poor oesophageal speech demonstrated some limitation to airflow or lack of fluency during assessment. A subpopulation of laryngectomized patients could not achieve airflow across the pharyngo-oesophagus. This group had achieved negligible oesophageal speech at the time of assessment and during insufflation no air entered the pharynx to produce sound, because of spasm in the pharyngo-oesophageal transition zone. A positive response to insufflation correlated with fluency in oesophageal speech. Characteristic responses were consistent across repeated trials. Coating of the pharyngo-oesophagus with barium during videofluoroscopy allowed excellent visualization of this segment of the pharynx and oesophagus on screening. Stricture of the pharyngo-oesophageal segment that would require surgical correction could also be accurately assessed. Results, interpretations and discussion clarify previously unresolved issues and have significant implications for the clinician in selecting a patient's method of alaryngeal communication.

Conventional versus computed tomography in patients with laryngeal tumours

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Previous studies have shown computed tomography (CT) to be valuable in staging laryngeal tumours although conventional tomography was still felt to have a place. High-resolution scanners and post-processing facilities such as multiplanar reformatting are now generally available. In view of these technological advances we have reassessed the role of plain radiography and conventional tomography compared with high resolution CT. Eleven patients (10 men and one woman) aged between 46 and 78 years (average 64 years) with carcinoma of the larynx were referred for radiotherapy following clinical examination and laryngoscopy. These included three supraglottic, five glottic and one transglottic tumours. One patient had an advanced pyriform fossa tumour involving the larynx, and one had a recurrence of a previously surgically treated glottic tumour. High resolution CT was performed in each patient, and sagittal and coronal reformatted images produced in nine patients. A lateral radiograph of the neck and conventional tomography were also performed. The extent of the tumours was evaluated in each case by two radiologists who were aware of the findings of the laryngoscopy and clinical examination. In none of the 11 patients did either plain radiography of the neck or conventional tomography add any information that could not be obtained from CT. In three patients cartilage involvement was demonstrated on CT which was not seen on conventional tomography. In seven of the nine cases where reformatted images were available they were felt to be at least of equivalent diagnostic quality to conventional tomography, and in four cases they were superior. In two patients neither conventional tomography nor reformatted images were of diagnostic value. Although we would not advocate radiological assessment in all patients with laryngeal tumours referred for radiotherapy, we feel that plain radiography of the neck and conventional tomography are no longer of value when high-resolution CT is available.

Ultrasound: Artefacts and Image Quality

Chairman: Prof. C. R. Hill

Physical factors affecting image quality
W. N. McDicken
Diagnostic implications of image quality in ultrasound
D. O. Cosgrove
The implication of speckle artefact in contrast discrimination
J. C. Bamber
The role of physical test objects in assessing image quality
K. McCarty
Diagnostic implications of image quality: the last word
H. B. Meire

Physical factors affecting image quality

W. N. McDicken
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The success of ultrasound imaging, like any other type of medical imaging, is highly dependent on the detail which can be portrayed. This detail is required to be optimized both in terms of spatial and contrast resolution. Many physical factors influence image quality, *e.g.* frequency, focusing, line density, beam width, side lobes and grating lobes, transducer performance, sensitivity settings, scan conversion, image processing, propagation of ultrasound in tissue, speckle noise, background ultrasonic and electronic noise, patient movement, display and recording techniques. These factors are considered and weighted as to their relative importance. Those factors most under the control of the operator are emphasized and suggestions are made to improve the reproducibility of ultrasound imaging.

Diagnostic implications of image quality in ultrasound

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In common with other imaging techniques, the interpretation of ultrasound relies on resolution (spatial, temporal and contrast) and is limited by maladjustments of the equipment and by unwanted signals. Spatial resolution sets limits to the smallest structures that can be detected, although, since about three cells must be altered to be reliably detected, the smallest resolvable lesion is larger than this. Axial resolution is determined by the wavelength; the increasing attenuation of ultrasound with higher frequencies limited the resolution for deeper structures, *e.g.* the abdomen. Lateral resolution is aperture dependent and attempts to improve it run up against the practical limitations of the maximum size of transducer that can be successfully contacted with the skin. Because it is usually easier to maintain contact with a linear than with an annular array, the former tends to give better resolution but only in the scanned plane, for the orthogonal aperture is low. Temporal resolution is determined by the frame rate. Is this is too low, movements seem jerky or are misregistered (aliasing). In the abdomen, few diagnoses rely on movement (though the unmasking effect of relative movement in assessing low-contrast boundaries is important) and available frame rates are adequate. Contrast resolution is the ratio between information and noise. Where this is low, differences in echo level are masked, *e.g.* with low-level artefact appearing in fluid spaces. This limits the ability to perceive lesions whose echo properties are subtly different from their background. Random noise may arise within the scanner or be generated in the patient. Structured noise has many sources (multiple reverberations, beam width, sidelobes) and is more troublesome because it produces apparent objects on the screen that may be repeatable and easily confused with abnormalities. Of the scanner controls, the TGC is the most commonly mis-set, leading to loss of information when parts of the image are too bright or too dark. Recently developed automatic systems seem able to improve on the best manual settings and will no doubt become widely used. Loss of useful information also occurs when strong patterns are overlain on the image; they distract and confuse the eye, camouflaging underlying structures. An everpresent form is speckle. Caused by the interference pattern between the coherent ultrasound beam and the tissue structure, it projects a dotted pattern over parenchymal regions that is often mistakenly interpreted as tissue texture. In fact, speckle reduces the ability to compare intensities and the speckle reduction filters that are being developed will be welcomed. Grosser problems that are not seen in modern equipment are the Moiré patterns that develop where scan lines beat with pixels in the memory, and contouring where too few grey levels are available, giving false edges. Examples of some of these effects are presented.

The implication of speckle artefact in contrast discrimination

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The last decade or so of development of ultrasound scanning instrumentation has seen substantial improvements in image quality, but mainly in terms of spatial resolution and its uniformity. Detection and diagnosis of diseased conditions is, however, a visual task requiring not only good spatial resolution but also good contrast resolution (*i.e.* discrimination) between pathology and its background of normal anatomy and tissue structure. Contrast resolution is determined at many stages in the imaging process, starting with the intrinsic contrast (between normal tissues and pathology) of the physical acoustic property being imaged, and involving most aspects of the signal processing and display, including the observer and any noise incorporated into the image. All medical ultrasound images suffer from a kind of noise known as speckle, which exists because coherent acoustic radiation is used to create the images and which causes their familiar and characteristic mottled appearance. At present, speckle represents the limiting factor for contrast resolution achieved in ultrasound echo imaging. Its presence has been shown to make a considerable difference to the contrast and/or size at which a lesion becomes visually detectable. It also interferes with a human observer's ability to identify changes in the tissue structural components of echo image texture. This paper reviews work of the past few years towards gaining an understanding of the properties of acoustic speckle, its effect on diagnostic procedures, methods for improving contrast resolution by removing the speckle and, finally, utilizing the speckle to improve the visibility of pathology.

The role of physical test objects in assessing image quality

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Physical test objects, such as those of the Cardiff Test System, are designed for use in comprehensive quality assurance programmes and consequently provide a means of measuring the large number of parameters which characterize the performance of a scanner. These parameters fall into two groups, those such as calliper accuracy, magnification error, etc., which check for compliance to an agreed tolerance, and those such as beam width, pulse length, dynamic range, grey scale transfer curve, penetration, etc., which are different for each scanner. It is this latter group which hold the key to quantifying image quality, although it is not easy to synthesize a single measure of image quality from the large number of parameters. In an attempt to reduce the number of parameters involved in specifying image quality, some workers have designed test objects containing targets such as spherical voids or low-contrast cones to measure simultaneously a combination of relevant parameters. Others have produced very detailed anthropomorphic phantoms in an attempt to enable a direct estimation of image quality. The most appropriate approach in any given situation will depend to a very large extent on why the assessment of image quality is being carried out. For instance, it may be argued that for quality assurance purposes, comparison of relevant parameters with previous values, irrespective of the form of the test object, will be sufficient. If, however, the aim is to assist in a purchase decision then the information from test objects will be used in a weighted sum of many diverse factors with the weighting coefficients being chosen after consideration of the proposed use of the scanner. In this situation each type of test object would seem to have a role to play.

Diagnostic implications of image quality: the last word

H. B. Meire
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Abstract not received.

PACS: Fact or Fantasy

Chairman: Dr J. O. Craig

PACS: an overview
J. O. Craig
Display, processing, transmission and storage: a system overview
G. H. Dombrowe
What the radiologist requires from PACS
D. J. Allison
PACS: the reality
P. Layzell
X-ray image acquisition technology for PACS
A. R. Cowen

PACS: an overview

J. O. M. C. Craig
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There has been an enormous increase in digitally acquired images in diagnostic radiology. There has been a surge of interest in total digital acquisition leading to the development of a filmless hospital. Despite an enormous input into the problems, from physicists, engineers, computer scientists and a few radiologists, there is still, worldwide, no filmless hospital. Initially, many of the problems were underestimated. The re-usable photostimulable phosphor cassettes have now been developed, but much work needs to be done on the methods of digital storage, transmission and retrieval. At St Mary's we are especially concerned with the ability to diagnose sophisticated subtle pathology on digital imaging. This diagnostic ability must be assessed by radiologists. A preliminary report was issued in September 1988, but new digitizers and monitors of higher specification have been installed. Work is in progress in assessing our diagnostic ability and this is crucial for the further development of totally digital hospitals, which we still believe will be constructed in the near future.

Display, processing, transmission and storage: a system overview

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Many of the individual components of PACS systems are available today and have even been tested in pilot installations of limited size. The experience gained has led to improved product solutions, which are now becoming available for more general introduction. The early installations have, however, also highlighted the considerable challenge that still lies ahead in creating full-scale, all-digital-imaging departments. Such systems are not merely a combination of existing components, but require a major effort in hard- and software engineering to achieve the required overall performance to cope with user demands in respect of data volume, speed and reliability. Strategies for realistic solutions are discussed, together with an overview of the latest technical advances in individual components.

What the radiologist requires from picture archiving communication systems

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Abstract not received.

PACS: the reality

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A number of PACS systems are functioning in hospitals in the United States. Their usage is varied and depends to some extent on the capabilities of the components installed. However, it is evident that the environment in which the system is installed also has an impact on usage. This paper describes the "reality" of PACS in two different clinical environments — one in a teaching hospital, the other in a community (general) hospital. These installations are mini-PACS systems designed to link dispersed CT and MR scanners using a fibreoptic network and with workstations for electronic viewing of images by radiologists and by clinicians. The objective of these clinical installations is to start a phased implementation of a fully integrated PACS system and to understand the impact and challenges of PACS for people using them in a number of different clinical settings. Although the installed systems were somewhat similar in terms of potential capability, the pattern of use has varied significantly. This paper describes each system configuration, the clinical application and usage at each hospital and the experiences of the radiologists, technologists and clinicians. The implications of this clinical experience on the development and growth of PACS in the clinical community are discussed.

X-ray image acquisition technology for picture archiving communication systems

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The introduction of PACS technology promises to have important ramifications for diagnostic radiology, promoting major changes in clinical work-practice and attitudes to equipment procurement. If PACS are to provide the comprehensive image management and archival service that busy diagnostic radiology departments will demand, they must be able to acquire and handle efficiently material from a wide range of imaging modalities. Imaging devices which incorporate more advanced technology (*e.g.* CT, MR, DSA, US, etc.) will in principle be immediately compatible with PACS technology. However, to be truly meaningful, PACS must also be fully compatible with the vast numbers of conventional radiological examinations which traditionally have used film as the image recording medium. In this presentation we review those digital X-ray image acquisition systems which (currently) promise to provide effective inputs to a PACS structure. Technology reviewed includes *digitized radiography, digital fluorography* and *computed radiography*. The important trade-offs between image specification, user ergonomics and capital equipment costs are examined. The advantage of evolving a modular PACS structure, which will make it possible to accommodate future advances in digital imaging technology, is stressed.

Radiotherapy: Consensus Management of Cancer

Chairman: Dr T. D. Bates

Clinical freedom or consensus management
  A. R. Timothy
Inappropriate management
  T. Brewin
Cost effectiveness in oncology
  G. J. G. Rees
Quality measurements for management planning
  P. Selby

Clinical freedom or consensus management

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Despite the increase in demand for cancer treatment (due to a rise in the proportion of elderly people in the population), resources are limited and the outdated concept of unfettered "clinical freedom" for the individual physician is now clearly inappropriate. Indiscriminate investigation which does not contribute to patient management is both irrelevant and wasteful. Likewise the use of intensive regimes of radiation or chemotherapy designed for cure may cause unnecessary morbidity when used for patients where palliation is the objective and where no active treatment or a simpler, cheaper option would be preferable. Apart from the additional morbidity, inappropriate treatment may also divert scarce resources away from patients where treatment would produce substantially greater benefit. There is an urgent need for all cancer physicians to consider not only the medical but also the social and financial consequences of their actions — failure to do so will lead to the responsibility for resource allocation being transferred to non-clinicians. This would constitute a genuine threat to clinical freedom for both patient and physician. Distinction needs to be drawn between treatment given for cure and that for palliation. Experimental treatment schedules should not be confused with routine clinical practice. There is an urgent need to establish broad guidelines for management which take account of information available from clinical trials and also consider resource implications in defining what may be appropriate and, as importantly, what is inappropriate care. This approach has already been successfully tried and tested in other fields of medicine and whilst the difficulties should not be underestimated, cancer physicians are more likely to obtain an adequate share of finite resources if they show themselves able to agree a rational basis for the treatment of individual malignancies. Perhaps the most important result of such an exercise, however, is that all cancer patients should have the benefit of the best advice and best treatment currently available.

Inappropriate management

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Management that is inadequate is clearly inappropriate, but it is customary to apply the word only to investigation or treatment that is excessive. This usually means that—judged by Lister's Rule ("if in doubt, put yourself in the patient's place") and by common sense, combined with an adequate knowledge of benefit and side-effects—a poor balance has been struck between prospects of benefit on the one hand and side-effects on the other. Treatment may also be more sophisticated and time consuming than is necessary. For example, in radiotherapy, the number of attendances and the duration of a course of treatment may be excessive, giving no better results than a shorter course (or even a single treatment). Simulators and other refinements are also sometimes used when they are unnecessary. Many cancer patients are elderly and even the safest and most non-invasive procedures may involve them in needless discomforts and delays. We must not let any test, treatment or procedure become just an unthinking routine or ritual. Resources will always be finite and the question of fairness to other patients also needs to be considered, not just in a local team context, but in a regional and national context. Greater attention to priorities releases time and money for more important purposes. Unfortunately, not only do we get into bad habits, but there are often insidious pressures of various kinds to do more than is really required.

Cost effectiveness in oncology

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The cost per year of life gained from the management of patients with cancer can vary from under £100 to approximately £1 000 000. Curative treatments are usually cheap but some palliative treatments can be very expensive indeed. The variation in treatment cost is even greater if adjustment is made for quality of life. Unrestrained clinical freedom can unfairly disadvantage other patients.

Quality measurements for management planning

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There is now general agreement that the outcome of the management of cancer patients should include consideration not only of their survival but also of the quality of that survival. These two aspects should be considered in planning the management of the individual patient, in conducting clinical research and in planning appropriate allocation of medical resources. The technical difficulties of measuring the quality of the cancer patients' lives have been widely discussed. The use of category rating and linear analogue self-assessment scales to collect data about subjective benefits for cancer treatments and also about the damaging effects of treatment is well recognized. In our own studies linear analogue self-assessment using 31 items has been shown to be a reliable and valid method of measuring subjective outcomes and these results are briefly reviewed and compared to alternative methods. The present on-going research is addressing the reduction of these questionnaires to a small number of appropriate questions which can be widely used in clinical practice and research. The integration of measurements of quality of life survival as an aid to the allocation of resources in Quality Adjusted Life Years (QALY'S) has been popularized by groups from San Diego in the USA and York in the UK. Such constructs are superficially attractive but they have been criticized on philosophical and scientific grounds. There is evidence which argues against the appropriateness of summing numerical scores for different aspects of quality of life into a single aggregate score. Most of the scales upon which QALY estimations have been based are not designed specifically for cancer patients and are insensitive to the sorts of changes which can be achieved with palliative cancer care.

Work in progress

Chairman: Dr R. J. Johnson

Combined papaverine test and isotope penile blood flow in the investigation of impotence
P. Grech, S. Dave, D. Cunningham and R. O'N. Witherow
Initial results of a randomized trial of laser-assisted percutaneous transluminal angioplasty (PTA) using the spectraprobe versus conventional PTA in peripheral artery occlusion
A. M. Belli and D. C. Cumberland
Self expanding metallic endoprostheses: an alternative to prostatectomy in high-risk patients
H. R. Jager, A. Adam, J. McLouglin, L. Machan, A. El-Din, G. Williams and D. J. Allison
Three-dimensional reconstructions of the injured spine
F. Mosshammer, F. Genelin and Ch. Primavesi
Magnetic resonance imaging of paediatric spinal cord injuries
J. T. Booysen, A. T. Scher and D. Newton
The use of single photon emission computed tomography and of indium-111 anti-CEA monoclonal antibody imaging in head and neck tumours
S. Ryan, D. Hamilton, B. Moran, M. Walsh, D. McShane and P. Freyne
Immunoscintigraphy of pelvic endometriosis
O. A. Mojiminiyi, S. H. Kennedy, B. J. Shepstone, M. D. W. Soper and D. Barlow
Evaluation of an electronic imaging device for verifying patient set-up in radiotherapy
J. P. Wade and D. Nicholas
Is transforming growth factor β (TGF-β) a mediator of late radiotherapy damage?
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Total lymphoid irradiation in chronic progressive multiple sclerosis
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S. C. Klevenhagen
The heating of diagnostic ultrasound transducers
F. A. Duck, H. C. Starritt and G. R. ter Haar

Combined papaverine test and isotope penile blood flow in the investigation of impotence

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The realization that many cases of impotence are amenable to treatment will result in a large increase in numbers referred for investigation. Current methods of non-invasive investigation include the papaverine test which, in most cases, will distinguish vascular from psychological or neurological causes, and the penile brachial index, which offers a crude assessment of arterial supply to the penis but is unable to detect small-vessel disease or assess the increase in penile blood flow during erection, a measurement that may be clinically more significant. A new test is described that combines the papaverine test with the measurement of penile blood flow, both in the flaccid state and during maximal vasodilatation. Blood flow is measured by isolating the penile circulation using a cuff inflated above arterial pressure. The remaining blood pool is labelled with $^{99}\text{Tc}^{\text{m}}$-labelled red blood cells. The rate of blood inflow into the penis is measured immediately after release of the cuff both before and after the intracavernosal injection of papaverine. As only the immediate inflow is measured, the effects of changes in penile size and differences in venous outflow are unimportant in interpretation. Preliminary results in 20 patients suggest that the method is a useful outpatient screening investigation. It replaces the simple papaverine test in excluding from further invasive investigation those patients who have a psychological or neurological cause for impotence. In addition, the choice between arteriography and cavernosography can be made in the remainder on the basis of the study.

Initial results of a randomized trial of laser-assisted percutaneous transluminal angioplasty (PTA) using the spectraprobe versus conventional PTA in peripheral artery occlusion

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Patients with total occlusion of the iliac or femoro-popliteal arteries were randomized to treatment using laser-assisted percutaneous transluminal angioplasty (PTA) or conventional PTA. Laser-assisted PTA was performed using a 2.5 mm spectraprobe (Trimedyne) and was followed by balloon angioplasty in every case. The spectraprobe is a probe that allows a small percentage of laser light to emerge through a window at its tip, converting the rest of the energy to heat and so combines laser light and thermal tissue interaction. The aims of the study are: (a) to assess whether there is any difference in primary success rate using the laser probe compared with the conventional guide-wire and catheter combination and (b) to assess whether there is any difference in the patency rate between the two techniques. Each patient was assessed at 1, 3, 6 and 12 month intervals by Doppler systolic pressures. The initial results presented are part of a multi-centre trial.

Self expanding metallic endoprostheses: an alternative to prostatectomy in high-risk patients

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A self-expandable metallic stent was implanted in the prostatic urethra of 14 male patients with bladder outflow obstruction, who were unfit for prostatic surgery. The patients were between 65 and 89 years old and had all had indwelling long-term bladder catheters. Two patients had had unsuccessful balloon dilatation of the prostate in the past. After a preliminary retrograde urethrogram, which allowed selection of a stent of the approximate length, the delivery catheter was inserted into the bladder over a guide-wire, using topical anaesthesia. Under fluoroscopic control, the distal end of the stent was placed just above the level of the bladder neck. The device was completely released, after having ensured that its proximal end was above the external sphincter. The inherent radial elastic forces of the device dilate the prostatic urethra, the average internal diameter being 1.1 cm. Post-procedural retrograde urethrography, micturating cystography, pelvic, and in some patients, transrectal ultrasound were performed in order to assess the position of the stent, bladder capacity and post-micturition residual volume. All patients voided spontaneously after the stent insertion and none of them had recurrence of outflow obstruction in the short follow-up period (maximum 4 months for the first patient treated). The flow rates ranged between 10 and 20 ml/s. Five patients had transitory urinary tract infections and four patients had mild stress or urinary incontinence, which settled after a few days, except for one patient who continues to have nocturnal enuresis. None of the patients had haematuria. All patients had no or a minimal residual volume after the procedure. Self-expanding endoprostheses are preferable to prostatectomy in high-risk patients and, if their long-term acceptability and safety are established, may replace surgery in virtually all patients with symptomatic benign prostatic hypertrophy.

Three-dimensional reconstructions of the injured spine

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In our hospital we have to deal with many lesions of the spine, often resulting from traffic or skiing accidents. We perform a CT examination in every case of severe trauma of the spine and in every case of discrepancy between clinical findings and plain radiography. It is necessary to produce reconstructions in sagittal and/or frontal planes to demonstrate the lesions optimally. Colleagues who are not familiar with axial cross-sections need reconstructions to get a clear idea of the problems. Three-dimensional (3D) reconstructions are performed if complicated and multiloculated fractures are found on CT. These images are more helpful in demonstrating multiple fractures of the vertebral body and arch than are common reconstructions. A special advantage is seen in the possibility of cutting away parts of the volume, so that a frontal or sagittal section with presentation of the structures behind can be achieved. Colour-coded reconstructions enable demonstration of not only bony windows but also other pre-set windows. Therefore, it is possible to show the spinal cord and other soft tissues in 3D reconstructions, together with the bony structures. Although 3D reconstructions do not provide new information to the radiologist, they are very helpful in demonstrating the injured spine to other physicians.

Magnetic resonance imaging of paediatric spinal cord injuries

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Research on recent spinal cord injury and the prognostic value of MRI in our series has been done on more than 200 patients including 13 paediatric patients. In a survey of 23 patients with stab wounds to the cord a correlation could be demonstrated between the MRI findings and the neurological follow-up and this was confirmed in an additional 57 patients with stab wounds. Spinal cord injury in children is uncommon and the incidence in reported series is less than 10% of all spinal cord trauma cases. Trauma to the spine in paediatric cases reacts differently to that in adults. The imaging protocol included T_1- and T_2-weighted studies in the sagittal and T_1-weighted images in the coronal plane where possible. Follow-up scans were obtained in seven patients. Ten patients were involved in motor vehicle accidents (five as pedestrians), one after falling in the slipstream of a train, one post-aorta-surgery and one after birth trauma. A bony abnormality could be identified on initial radiographs in two patients and after flexion views in one patient performed after conservative treatment. The cord trauma could be demonstrated on MRI in all of these patients. A cord contusion or ischaemia leading to cord atrophy, which may be short segmented or total distal atrophy, was demonstrated in 11 patients. These findings are unique to the paediatric group, but also provide additional information on the prognostic value of MRI and are discussed in detail.

The use of single-photon emission computed tomography and of indium-111 anti-CEA monoclonal antibody imaging in head and neck tumours

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A technique for detecting nodal involvement in head and neck tumours would help greatly in patient management, since clinical assessment alone is often difficult, particularly in patients who have had surgery and/or radiotherapy to the neck with resultant extensive scarring. We are looking at the role of monoclonal antibody imaging in patients known to have head and neck squamous cell carcinoma. The radionuclide indium 111 has a number of advantages over other radionuclides for this type of imaging in this particular area. When combined with SPECT, a sensitive technique for localizing small areas of increased uptake is achieved. The images may then be compared directly with images obtained from CT and the results of the studies correlated with *in vitro* monoclonal investigations on biopsy samples and serum. We present the findings in a number of patients, detail the problems encountered and suggest future developments.

Immunoscintigraphy of pelvic endometriosis

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Endometriosis is the presence of functioning endometrial glands and stroma anywhere outside the uterine cavity.

Endometriotic tissue has been found to express CA-125, an antigen found in ovarian carcinoma. This study was set up to evaluate prospectively the possibility of localizing areas of endometriosis using radiolabelled OC-125, a murine monoclonal antibody that reacts with CA-125 and has been used to localize primary and metastatic sites in women with ovarian carcinoma. Sixteen women with clinical suspicion of endometriosis have been studied. Each patient received 74–100 MBq of ^{131}I- or ^{111}In-labelled antibody F(ab')$_2$ fragments. Immunoscintigraphy was positive in 13 (81%) patients in whom endometriosis was subsequently confirmed at laparoscopy/laparotomy. Immunoscintigraphic findings were equivocal in one patient with concurrent gastrointestinal tract infection at the time of investigation, and negative in two patients. Only one of the patients had an elevated level of serum CA-125. These results and the possible pathogenic mechanism of the immunoscintigraphic localization are discussed. Despite the excellent correlation between surgical and immunoscintigraphic findings, more patients need to be studied before definitive recommendations can be made.

*On IAEA Fellowship.

Evaluation of an electronic imaging device for verifying patient set-up in radiotherapy

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Quality assurance of patient set-up and beam delineation with respect to the desired treatment volume becomes increasingly important as treatment set-ups become more complicated. Verification radiographs are widely used for this purpose, despite the inherent low contrast that makes interpretation difficult. A new imaging device, Dynaray ID, is being marketed by ASEA Brown Boveri (ABB) and is intended as an alternative to verification radiographs. The Dynaray ID imaging system consists of a detector with a sensitive area of 32.5 cm × 32.5 cm divided into 256 × 256 pixels and connected to a desk-top computer where the images are processed either automatically or under operator control. At Norwich we are undertaking a full evaluation of this imaging device, including measuring its physical limitations, its ease of use with patients and assessing the information obtained. A direct comparison is being made between the Dynaray ID images and verification radiographs and an assessment made of comparability to simulator radiographs for quantitative measurements of field placement errors. The detector can also be regarded as an array of dosemeters giving a detailed description of the exit dose distribution, and this facility is aiding measurements being done on a tissue compensation system that has been introduced recently at Norwich.

Is transforming growth factor ß (TGF-ß) a mediator of late radiotherapy damage?

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TGF-ß is a multifunctional peptide that has a fundamental role in regulating cellular growth and biochemistry. It has a marked ability to enhance the formation of connective tissue *in vivo*, it can cause endothelial proliferation *in vivo* and can also result in epithelial cell growth inhibition. TGF-ß has been sought in six patients who had received irradiation (50Gy in 5 weeks) prior to surgery (radiotherapy/surgery intervals 7, 8, 9, 10, 27 and 40 weeks) and in three patients treated by surgery alone for large bowel tumours. A polyclonal rabbit anti-TGF-ß antibody detected TGF-ß in paraffin-fixed sections using a labelled avidin method. TGF-ß was found in the non-tumour-bearing tissue of four out of six irradiated but none out of three non-irradiated patients. TGF-ß was found in association with macrophages in the stroma (4/6), macrophages within blood vessels (2/6), in blood vessel walls (3/6) and radiation-deformed epithelium (3/6). The staining was not uniform and there was marked interpatient variability. The tumour was positive in five out of six irradiated and three out of three non-irradiated patients. The co-existence of TGF-ß and radiation damage in these patients provides support for a working hypothesis that TGF-ß is implicated in the pathogenesis of late radiation fibrosis and hypoxia. This implies that late radiation damage is a result of biochemical factors not unique to radiotherapy and that it is a factor of abnormal repair either in addition to, or instead of, being directly caused by an immediate effect of radiotherapy at a cellular level.

Total lymphoid irradiation in chronic progressive multiple sclerosis

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The trial is designed to test the hypothesis that total lymphoid irradiation halts or reduces clinical deterioration in chronic, progressive multiple sclerosis with acceptable side-effects. It is planned that 60 patients in total will be assigned randomly to total lymphoid irradiation or "sham" irradiation. All patients are simulated for upper mantle and inverted "Y" treatment and have full work-up before randomization into one of the two treatment options. The upper mantle (including spleen) is treated to 1980 cGy in 12 fractions treating daily followed without a break by the inverted "Y" treatment of 1980 cGy in 12 daily fractions using 8MeV X rays on a Philips SL 75-100 accelerator. Assessment (blind) uses clinical measures (neurological and physiotherapeutic), quantitative magnetic resonance imaging, psychometry, subjective scales and studies of peripheral blood lymphocyte numbers, subsets and function. The results of the first 20 patients randomized are presented and include toxicity data lymphocyte counts during the first 18 months of the trial. Problems encountered in the management of chronic neurologically sick patients in the Radiotherapy Department are highlighted. The use of irradiation in a "benign" condition is discussed as well as the difficulty of obtaining informed consent.

An analysis of backscatter factors for X-ray qualities between 0.1 and 4 mm aluminium half-value layer

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An International Code of Practice for radiation dosimetry has recently been published by the IAEA (1987). In Section 7.2 of this report dealing with low-energy X-ray dosimetry, a set of data on backscatter factors is given, which differs significantly from the backscatter factors published in *British Journal of Radiology Supplement 17* (1983). The IAEA data are based on theoretical calculations performed by Grosswendt (1984) and it was thought that they required experimental verification, which was carried out in the present study. A special 3 mm thin, plane-parallel ionization chamber was constructed for this work and measurements were performed using water as a scattering medium. The experiments involved field sizes from 2.0 to 20 cm beam diameter and X-ray qualities between 0.1 and 4 mm Al. The results yielded backscatter factors in close agreement with those obtained by Monte Carlo calculations, although some discrepancies occur at small field sizes.

The heating of diagnostic ultrasound transducers

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The surface temperatures of 30 diagnostic ultrasound transducers have been measured during conditions of maximum drive power, operating in air. Measurements were made with an infrared radiometer or with a thermocouple probe. Arrays, mechanical sectors and Doppler transducers were included amongst the transducers studied. The greatest temperature rise observed during imaging operation was 13.1 °C giving a surface temperature of 38.5 °C. This temperature could just be perceived when the transducer face was touched. In pulsed Doppler mode, several transducers operating with one particular duplex scanner became excessively hot under certain drive conditions. The highest surface temperature measured was almost 80 °C after 5 min operation in air. If such temperatures are maintained on the skin, burning may occur within seconds. A summary of all temperature increases are shown. It is demonstrated that temperature increase bears a close to linear relationship to source intensity for any particular type of transducer. It is also shown that array transducers show an approximately 10-fold higher heating rate than that shown by Doppler probes. The surface temperatures of mechanical sectors lie between these extremes. Thermal images are shown demonstrating the effect on the skin of those transducers found to give the highest temperatures in both imaging and Doppler modes. It is concluded that the thermal design of diagnostic ultrasound transducers is critical for their safe use.

Ultrasound: proffered papers and posters

Chairman: Dr W. Hateley

Stroke risk factors and carotid plaque size
A. D. White, G. Carolan, M. J. S. Pathy and J. P. Woodcock
The investigation of chronic venous insufficiency by duplex scanning
G. McMullin, P. D. Coleridge-Smith and J. H. Scurr
Does duplex scanning have a role in aorto-iliac disease assessment?
V. M. Gazzard, M. D. McShane, K. McHugh and A. D. B. Chant
Screening for aortic aneurysms: are male hypertensives at risk?
W. G. Tennant, D. J. A. Scott, M. G. Wyatt, F. Difford, H. Andrews and M. Horrocks
Duplex ultrasound studies of the portal vein in portal hypertension
I. L. Green, M. J. P. Arthur, C. M. E. Rubin and K. C. Dewbury
Cavernoma of the portal vein: radiological findings and aetiological basis
S. Olliff, M. Stringer, J. Karani and E. R. Howard
The role of duplex Doppler in the staging and characterization of pancreatic tumours
S. J. Garber and W. R. Lees
Staging pancreatic cancer: does it matter?
W. R. Lees, S. N. Jones and R. Chisolm
Evaluation of pre-operative abdominal ultrasound in patients with carcinoma of the oesophagus
E. J. Fitzgerald and J. P. Murphy
Ultrasound evaluation of gallbladder dynamics in normal subjects
P. M. Hughes and D. F. Martin
Abdominal ultrasound: the diagnostic yield in patients referred directly by their general practitioners
P. Mills, A. E. A. Joseph and E. J. Adam
Financial savings in relation to a general medical ultrasound service
H. H. Huang and J. A. Eggington
Routine ultrasound assessment of all new patients attending a general gynaecology clinic
M. J. O'Dowd
Ultrasound-guided fine-needle aspiration in the diagnosis and treatment of ovarian cysts
K. T. Khaw and W. J. Walker
Ultrasound of the axilla: the technique and its role in staging breast carcinoma
P. McCarthy and P. Keane
The use of real-time orbital ultrasound in Graves' ophthalmopathy: a comparison with computed tomography
R. M. Given-Wilson, R. Pope and M. J. Michell
Heterotopic bone formation: the role of ultrasound in its early diagnosis and management
V. C. Pullicino, E. A. Thomas and I. W. McCall

Stroke risk factors and carotid plaque size

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A number of risk factors contribute to stroke disease. About 50% of strokes are caused by emboli arising from atheromatous plaques in the carotid arteries. The reason why plaques become dangerous and embolize is uncertain, although those causing more than about 75–80% stenosis are more likely to do so. This study considers the relation between risk factors and plaque size. As part of a study of carotid plaque morphology using duplex ultrasound, note was made of hypertension, myocardial infarction, diabetes mellitus, peripheral vascular disease and smoking. The presence or absence of the risk factor was correlated with the presence of minor (<75%) or major (>75%) plaque and with the occurrence of ischaemic events; 1180 patients were examined over 3 years. A number of significant correlations were noted: hypertension with major plaque in the right internal carotid artery ($p = 0.05$), myocardial infarction and major plaque in the right internal carotid artery ($p = 0.0024$), left common carotid artery ($p = 0.03$), left internal carotid artery ($p = 0.005$), and left external carotid artery ($p = 0.01$), peripheral vascular disease with major plaque in the right internal carotid ($p = 0.0008$), right external carotid ($p = 0.04$), and left internal carotid ($p = 0.0001$), smoking with major plaque in the right common carotid ($p = 0.01$) and right internal carotid ($p = 0.004$). In respect of ischaemic events, strong correlations were found between myocardial infarction and stroke in general ($p = 0.005$), peripheral vascular disease and right and left carotid bruit ($p = 0.002$) and smoking with transient ischaemic attacks ($p = 0.0001$) and carotid bruits ($p = 0.0001$). It is concluded that some of the risk factors for stroke may influence the development of carotid plaques. The combination of a risk factor and major plaque is probably more dangerous to the patient than either alone.

The investigation of chronic venous insufficiency by duplex scanning

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Chronic venous insufficiency of the lower limb is a common problem. Effective surgical management relies on correct identification of the site(s) of valvular incompetence. This is impossible by clinical examination alone. Until recently, ascending and descending venograms were required. The non-invasive methods of investigation available gave limited information and were not wholly reliable. Duplex scanning employs B-mode ultrasound to image the veins of the leg. This facility is combined with a pulsed Doppler ultrasound signal to determine the presence or absence of forward and of reverse flow within a particular vein. In this way a complete anatomical and functional survey of the venous system is obtained. One hundred and four limbs with signs of chronic venous insufficiency were examined by duplex and continuous-wave Doppler ultrasound.

Diagnosis made by duplex	*n*
Deep venous insufficiency	39
Long saphenous insufficiency	28
Short saphenous insufficiency	10
Long + short saphenous insufficiency	3
Incompetent perforating veins	24

There was concordance between duplex and Doppler in 62% of cases. It is concluded that duplex scanning provides an accurate non-invasive method suitable for screening large numbers of patients with venous disease. This study indicates that two-thirds of patients with chronic venous insufficiency would benefit from established venous surgical procedures.

Does duplex scanning have a role in aorto-iliac disease assessment?

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In Southampton, duplex scanning has been developed and used to assess arterial disease in the femoro-popliteal segment. Comparison of arteriography with duplex scanning for this segment show accuracy, sensitivity and specificity of 97% when differentiating between disease of less than or greater than 50% diameter constriction. Furthermore, duplex scanning can accurately locate any disease present non-invasively. Detailed examination of the aorto-iliac arterial segments is now under development. Fifty-four patients undergoing biplanar arteriography as a routine part of their hospital management have also been examined by duplex scanning. In all these patients a continuous scan from the aorta, along the common iliac and into the external iliac artery was attempted. Information from both the B-scan and Doppler waveforms was used to assess any disease present and to localize the disease where possible. Using biplanar arteriography as a gold standard, duplex scanning has a specificity of 93%, sensitivity of 86% and overall accuracy of 91% when differentiating between disease of less than or greater than 50% diameter constriction. In a number of patients it was possible to localize the disease to a specific artery or even to a particular part of that artery. In those patients in whom exact location of the disease was not possible, the disease location could be defined to within a segment. Duplex scanning of the aorto-iliac segment does have limitations, especially with bowel gas or obesity. However, it has been shown in this study that it is possible to locate accurately and determine the extent of disease in many patients and it can be used as a screening test. In some patients it may replace the need for arteriography.

Screening for aortic aneurysms: are male hypertensives at risk?

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Screening for aortic aneurysms has been proposed in an attempt to reduce the mortality associated with rupture. Hypertension has been postulated as a significant risk factor. We have investigated the effect of hypertension on aortic size in 209 male patients. Three groups were studied: Group 1, 88 normotensive male general practice (GP) patients; Group 2, 87 hypertensive male GP patients, well controlled on medication; and Group 3, 34 males admitted to hospital for treatment of severe hypertension. All patients were examined and the maximum antero-posterior aortic diameter measured.

Group	Mean age (years)	Diastolic BP (mmHg)		AP aortic dia (mm)		Number of cases of AP aortic dia		
		Mean	SEM	Mean	SEM	<24 mm	25–39 mm	>40 mm
1	66	82	1.14	19.6	0.51	83	3	2
2	65	91	1.18	18.9	0.64	81	5	1
3	57	94	2.25	21.9	1.15	25	8	1

There was a significant difference in the mean diastolic blood pressure between the normotensive GP patients and the other two groups ($p < 0.001$ in both cases). Both normotensive and hypertensive GP patients had smaller aortas than the hospitalized hypertensive patients ($p < 0.02$, < 0.001, respectively). Four patients had aortic aneurysms over 40 mm diameter. These results support the contention that there may be an increased risk of the development of aortic aneurysms in severely hypertensive males. This increased risk does not appear to apply to males with well controlled hypertension.

Duplex ultrasound studies of the portal vein in portal hypertension

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Portal hypertension is an important cause of morbidity and mortality in cirrhotic patients. Chronic parenchymal changes in cirrhosis increase the vascular resistance, which in turn increase the portal pressure and decrease portal blood flow. Doppler ultrasound combining Doppler with real-time B-mode imaging is a relatively simple method for assessing portal vein blood flow. In this study we used a Toshiba Sonolayer with Doppler attachment to assess portal blood flow in a control group and in a group of portal hypertensive patients. Measurements were taken of portal vein diameter, mean blood velocity and absolute volume flow. The portal flow measurements were found to be reproducible with a coefficient of variation of 7.7%. Eating almost doubled portal flow and all subsequent studies were performed with the subjects fasting for at least 4 h. There was no significant difference in the portal vein diameter between the control group and the portal hypertensive group (9.2 mm compared with 9.8 mm). However, there was a significant difference in both the mean velocity and the mean blood flow.

Mean velocity in the control group was 14.33 cm/s compared with 3.9 cm/s in the portal hypertensive group in which two patients had flow reversal in the portal vein. Mean flow was 561 ml/min in the control group compared with 154 ml/min in the portal hypertensive group. We conclude that duplex ultrasound is a relatively simple, non-invasive and reproducible technique, which is likely to prove valuable in the diagnosis and management of portal hypertension.

Cavernoma of the portal vein: radiological findings and aetiological basis

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Portal vein occlusion with a normal liver is an important cause of portal hypertension that may present with gastrointestinal bleeding from varices in both adults and children. Occlusion has been attributed to neonatal intra-abdominal or umbilical sepsis or surgical intervention. Other underlying conditions include haematological disorders resulting in hypercoagulation. In a large number of patients the aetiology is obscure, possibly being of developmental origin. The imaging of 30 patients with long-standing portal vein obstruction shown by collateralization of the main portal vein is reviewed. The pattern of collateralization and shunting is studied. Particular reference is made to the presence or absence of intrahepatic portal venous radicles. Correlation of the angiographic and ultrasound findings is made with age, potential aetiological factors and liver biopsy results. The findings are presented and discussed.

The role of duplex Doppler in the staging and characterization of pancreatic tumours

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The advent of duplex Doppler has permitted accurate definition of the vascular changes associated with abdominal tumours. Pancreatic tumours may alter the surrounding vessels in several ways. Easiest to detect is involvement of contiguous vessels, with the portal vein most commonly affected. This is seen as a complete loss of flow in total occlusion, an increase or decrease in flow velocity in constriction and the development of turbulent flow in vessel wall invasion. Characteristic flow signals are detectable in the tumour itself. A high-velocity signal is seen with arterio-venous shunts and a low velocity non-pulsatile signal with the low impedance vessels seen in neovascularization. Feeding vessels, usually the gastroduodenal artery, may demonstrate increased flow rate and a reduction in impedance associated with reduced distal vascular resistance. This study describes our experience of Doppler assessment in 50 cases of pancreatic tumour. Patients were scanned on an Acuson 128 machine with a 3.5 MHz phased array probe. Ten per cent of cases demonstrated complete portal vein occlusion, 36% showed constriction of the portal vein and in 45% there was evidence of vessel wall invasion. Doppler signals indicative of an arterio-venous shunt were seen in 15% of cases and in 32% there was evidence of neovascularization. Subsequent correlation of patient survival with ultrasound staging is made, including data on proximal cholangiocarcinomas. These results confirm the invaluable role of Doppler ultrasound in precise staging of portal vein wall invasion and in differentiating benign from malignant lesions by the characteristic flow signals. Doppler now forms an essential part of abdominal tumour examination.

Staging pancreatic cancer: does it matter?

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One hundred patients with histologically proven pancreatic cancer underwent careful staging with ultrasound and the features were compared with the histology and correlated with the patients' survival. The tumour size varied from 8 to 70 mm (mean 36 mm). The tumour load was less than 30 ml in 80% and greater than 500 ml in only five patients. The average tumour volume was 27 ml at presentation and 76 ml just prior to death. Eight of the patients had pancreatic ductal adenocarcinoma. Seventy-nine per cent of these tumours had lobulated or spiculate margins, 83% were echo poor and calcification was not seen. Involvement of the portal vein was seen in 71% and local invasion beyond the pancreas in 55%. Regional lymph node involvement was demonstrated in 75%. Liver metastases were seen in only 15%. There were strong independent and linked correlations between tumour size, lymph node involvement, local invasion and poor survival. There was no correlation between the degree of tumour differentiation, internal acoustic features or survival. The situation with tumours of other histology was quite different. Cysts or calcification were seen in 10% and 5%, respectively. Over 50% of the tumours presented a smooth, rounded margin. Portal vein involvement was seen in only 21% and node involvement in 42%. Only 10% showed local invasive characteristics. Survival and local invasive characteristics and node involvement was strongly related to tumour tissue type. State-of-the-art ultrasonography can provide all the information necessary to stage pancreatic carcinoma and, if coupled with histology, allows good prediction of prognosis and operability. The outlook for ductal adenocarcinomas of larger than 20 mm diameter is very poor.

Evaluation of pre-operative abdominal ultrasound in patients with carcinoma of the oesophagus

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A prospective study to evaluate the accuracy of ultrasound in assessing intra-abdominal spread from oesophageal carcinoma was undertaken. The results of 50 consecutive abdominal sonograms performed prior to oesophagogastrectomy were correlated with the operative and histopathological findings. All examinations were performed on a General Electric RT 3000 ultrasound machine using a 3.5 MHz sector probe. Of the 50 cases studied, 42 of the examinations were reported as normal and eight as having hepatic metastases and/or intra-abdominal lymphadenopathy. Of the eight abnormal investigations, five were reported as having hepatic metastases alone, two showed evidence of nodal involvement alone, and one showed both hepatic and nodal deposits. These findings concurred with the operative findings. There was one false negative among the 42 examinations reported as normal. In this case a small superficial deposit in the left lobe of the liver was seen at operation. These findings suggest that routine pre-operative abdominal ultrasound in these patients is accurate in detecting hepatic metastases and larger nodal deposits. It is important in such patients to have an accurate method of pre-operative assessment of spread as it allows the surgeon to plan the most appropriate method of treatment for this malignancy. When deposits are shown they may be resected in conjunction with the primary tumour, or palliative oesophageal intubation rather than oesophageal resection may be performed.

Ultrasound evaluation of gallbladder dynamics in normal subjects

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Non-surgical management of gallbladder stones requires the assessment of gallbladder function, usually evaluated by oral cholecystography or cholescintigraphy. The accurate assessment of changes in gallbladder volume during emptying and filling phases may be difficult using these methods and the repeated use of ionizing radiation is best avoided. We have developed a simple technique for the ultrasound estimation of gallbladder volume changes following a standard palatable, fatty meal and have evaluated its use in normal volunteers. Twenty-one subjects were studied, 10 men and 11 women, mean age 33 ± 12 years. A Siemens SL2 with a 3.5 mHz mechanical sector scanner was used and gallbladder length, transverse and vertical diameters were measured. Volume was estimated using the ellipsoid formula programmed into the scanner software. Estimations were made following an overnight fast, administration of a fatty meal and during subsequent gallbladder filling. A second fatty meal was given and the reproducibility of emptying was assessed. The mean overnight fasting volume was 18.6 ± 9.5 ml. The 4 h fasting volume was 16.9 ± 7.8 ml. Emptying after a fatty meal was linear with a rate of 3.1 ml/min and the mean ejection fraction was 49.6 ± 21% of the resting volume. Eighty-five per cent of subjects achieved maximum gallbladder emptying by 45 min. Filling was linear with a mean rate of 2.3 ± 0.7 ml/h and gallbladder volume reached overnight fasting volume by 4 h in 80% of subjects. Fasting duration, age, sex or the body weight did not influence gallbladder emptying or filling. Ultrasound measurement of gallbladder emptying and filling is simple, safe, rapid, non-invasive and cheap and can be undertaken during a morning or afternoon list after a fasting period of 4 h.

Abdominal ultrasound: the diagnostic yield in patients referred directly by their general practitioners

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The proportion of patients referred for radiological examination by their general practitioner (GP), in whom a significant abnormality is found, is claimed to be low for many types of examination. We have compared the results of abdominal ultrasound in 1000 adults, of whom 500 were referred directly by their GPs and 500 via the hospital outpatients' department. It is our practice to examine the entire abdomen, even if pathology is suspected only in a specific organ. The results showed that a significant abnormality was detected in 35.2% of the GP referrals and 42.9% of the outpatient referrals. Small cysts in the liver and kidney, mild prostatic enlargement and mild fatty infiltration of the liver in the absence of symptoms or a history of alcohol were classified separately. The most common significant abnormality was gallstones. In 299 GP patients referred specifically to look for gallstones, 18% were positive and in 108 outpatient referrals, 19.5% were positive. In the GP referral group, two unsuspected carcinomas were diagnosed. The rate of detection of significant abnormalities in patients referred by their GP is high. We believe that an ultrasound service is of benefit to general paractitioners and may well be cost effective.

Financial savings in relation to a general medical ultrasound service

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In a retrospective study into the impact of a fully established general medical ultrasound service (excluding antenatal and cardiac scans) in a large district general hospital, it was found that in the Körner year 1987/88, there were minimal quantifiable annual savings in relation to equipment and consumables of £15 752.24. Of this, consumables amounted to £7891.00, representing actual redeployable savings. Of 2485 patients scanned, a sample of 621 (25%) of the requests were analysed. Our findings are that major savings lie outside the imaging department. They consist of reductions in the number of outpatient visits by shortening the investigative chain, and reduced operative intervention, bed stay and morbidity. In relation to X-ray room utilization there are savings in fluoroscopy time, and in the need for dedicated IVU facilities. While there is a real reduction in angiographic needs, screening time for localization and invasive procedures is being replaced by the need for this facility in other investigative areas. Scanning in place of paediatric and some adult IVUs, in chronic renal failure, and in the investigation of the non-functioning kidney produces savings amounting to £7110.92. Other major financial savings lie in relation to investigation of the liver, biliary tract and pancreas (£3854), with reduced need for CT and other more costly and invasive procedures. A separate analysis of a reduction in outpatient cholecystograms annually by 661 shows a relatively modest consumable-based saving of £1983. General observations in relation to staffing indicate re-deployment of radiographers rather than any reduction. The scanning radiologist may only need the assistance of a radiography helper, but the technique can take up a considerable proportion of sessional time.

Routine ultrasound assessment of all new patients attending a general gynaecology clinic

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In many countries pregnant women are screened routinely by ultrasound. This is not the case with gynaecology patients, where ultrasound examination is limited to specific indications, *e.g.* infertility, oligomenorrhoea and amenorrhoea, lower abdominal and pelvic masses, evaluation of menorrhagia, and diagnosis and follow-up of genital cancers. The aims of this study were to evaluate the use of routine ultrasound for all first attenders at a general gynaecology clinic, conduct a feasibility study, explore the problems engendered by its use and estimate possible benefits. Five hundred consecutive outpatients were admitted to the study. Each patient had a full history, with gynaecological examination and sector scanning. Ultrasound was performed in the clinic by the author. All patients had per-abdominal scans and a minority required intravaginal scanning. Data on ultrasound examinations were recorded on special forms designed to ease information retrieval. The main diagnostic groupings were: abdominal pain (13%), menorrhagia (12%), urinary disorders (11%), oligomenorrhoea and amenorrhoea (10%), infertility (8%), intermenstrual bleeding (8%) and prolapse (5%). A further 25 diagnostic categories made up the remaining 35% of cases. Routine ultrasound assessment proved feasible. The main problem encountered was delay while awaiting bladder filling, but this was eventually overcome in the majority of instances. Some benefits were immediately obvious, *e.g.* detailed knowledge of the pelvic organs, and reduction in blood tests for hormone levels. Admissions for laparoscopy and diagnostic D + Cs were reduced. Ultrasound evaluation of gynaecology patients is beneficial, cost effective and should be availed of more frequently.

Ultrasound-guided fine-needle aspiration in the diagnosis and treatment of ovarian cysts

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Ovarian cysts may cause symptoms and undergo torsion or rupture, and, in post-menopausal women, have a higher incidence of malignancy. The accepted management of ovarian cysts has included laparotomy or laparoscopy, which usually involve admission to hospital and the risks of general anaesthesia and surgery. Laparoscopy is also associated with a higher rate of complications and technical failure in patients with pelvic inflammatory disease or adhesions. We have performed ultrasound-guided fine-needle aspiration (FNA) of ovarian cysts in 20 patients for both diagnostic and therapeutic purposes. The appearances on ultrasound and the result of cytological examination were documented in all cysts and correlated to histology if surgery was later performed. Three patients were pregnant, and aspiration was performed transvaginally in one of these. Follow-up ranged from 2 months to 4 years. One cyst with echogenic cyst contents and haemorrhagic aspirate proved malignant. The remainder were benign and of these three recurred. Ultrasound-guided FNA was performed on an outpatient basis under local anaesthesia and no complications occurred. Ultrasound can identify benign cysts with a high degree of accuracy. When FNA cytology is performed in an ultrasound benign cyst the risk of missing malignant disease is minimal. If there are ultrasound criteria of malignancy such as septae or nodules, however, FNA should not be the sole method of management, as a negative cytological result cannot exclude malignancy. In these patients surgical assessment is desirable. Fine-needle aspiration under ultrasound control is best suited to the management of ultrasonographically benign unilocular cysts in pre-menopausal women, in whom it is a simple, safe procedure with few complications. The technique is also useful in pregnant patients and in other patients unsuitable for surgery or general anaesthesia.

Ultrasound of the axilla: the technique and its role in staging breast carcinoma

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The single most important prognostic indicator in breast cancer is axillary node status. An accurate method of detecting axillary disease may spare the patient considerable morbidity from surgical excision of nodes (possibly combined with radiotherapy). Clinical examination is known to be inaccurate in a significant number of patients. The technique of axillary ultrasound examination is outlined. Twenty-eight consecutive patients with biopsy-proven carcinoma of the breast were examined with ultrasound on the morning prior to definitive surgical treatment (which included axillary node clearance in all cases). The radiologist examined both axillae without knowledge of the clinical findings. Seventeen patients had node-positive disease, of whom 12 patients were detected on ultrasound, but only eight clinically. One patient had a false positive ultrasound scan, the node being found at histology to contain only inflammatory tissue. More recently, four patients had pre-operative fine-needle aspiration biopsy of five nodes under ultrasound guidance, all of which yielded metastatic disease. In conclusion, we believe ultrasound to be superior to clinical examination in detecting axillary node disease and a useful adjunct in the work-up of breast cancer patients.

The use of real-time orbital ultrasound in Graves' ophthalmopathy: a comparison with computed tomography

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Evaluation of the severity of orbital involvement and likelihood of the development of optic neuropathy in Graves' disease can be difficult clinically. We describe the use of real-time orbital ultrasound scanning to measure medial rectus muscle width in 20 patients with Graves' ophthalmopathy and 21 normal individuals. The normal reference interval (to 2 SDs) was 1.75–4.07 mm. Significantly ($p < 0.001$, Mann Whitney *U*-test) larger values were observed in patients, and there was good correlation between the medial rectus width and a clinical index of disease severity in individual eyes ($p < 0.001$, Spearman rank correlation coefficient). Comparison of the medial rectus measurements was obtained using computed tomography (CT) and ultrasound of the orbit showed positive correlation at the $p < 0.001$ significance level (Deming regression). Medial rectus measurements on CT also correlated with both horizontal and vertical muscle indices for that orbit, these measurements are also reported to relate to the risk of development of optic neuropathy (Barrett et al, 1988). We suggest that real-time ultrasound measurement of medial rectus width using widely available equipment provides an accurate, simple and non-invasive means of evaluating the orbits of Graves' disease patients, and that repeated measurements may be of use in both identifying patients at particular risk of visual failure and following the response to therapeutic strategies.

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Heterotopic bone formation: the role of ultrasound in its early diagnosis and management

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It is generally accepted that "heterotopic bone formation" should replace "myositis ossificans" as the correct term describing a distinct soft-tissue entity. It is characterized by an initial soft-tissue inflammatory lesion followed by heterotopic ossification. The early inflammatory phase clinically mimics tumour, infection and deep venous thrombosis. Radiographically and pathologically the appearances may be mistaken for bone and soft-tissue sarcoma. The early radiographic features are non-specific and diagnosis can be extremely difficult. The role of ultrasound scanning in the early, uncertain time of presentation is compared with other imaging methods, including plain radiography, computed tomography and radionuclide studies. Prospective studies of the echographic appearance in seven patients with heterotopic bone formation are described. Its unique evolution is clearly demonstrated by sequential ultrasound assessments, while the depiction of "zone phenomenon" in the maturation process allows a confident diagnosis before the radiographic features of new bone formation. Early ultrasound diagnosis has distinct advantages with therapeutic implications.

Interventional Radiology

Chairman: Prof. A. P. Hemingway

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Reliability of percutaneous transhepatic cholangiography, endoscopic retrograde cholangiopancreatography and ultrasound in obstructive jaundice
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Recent advances in peripheral artery recanalization

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Percutaneous transluminal angioplasty (PTA) of arterial stenoses and occlusions has become a well established and relatively safe technique in the treatment of peripheral vascular disease. The main problem, however, is recurrent disease. Several new methods of recanalization have been developed in an effort to overcome this problem. Thrombolysis is used in the treatment of acute occlusions but is of less value in chronic occlusions. Laser light from the near ultraviolet to the mid infrared can ablate atherosclerotic plaque and is therefore being used in the treatment of arterial occlusions. The original bare laser fibre caused an unacceptably high perforation rate so the delivery system has had to be modified. There are currently many ingenious modifications being evaluated, such as the multifibre laser catheter with optical shield, the sapphire contact probe, the lensed fibre tip, the metal laser probe (hot tip) and the hybrid laser probe (spectraprobe). Mechanical devices are also being used for percutaneous recanalization, such as the Simpson atherectomy catheter which cuts protruding atheroma from the wall, and the Kensey catheter which employs a battery driven rotating cam. Endovascular stenting is a method under evaluation for maintaining patency in diseased vessels. Such stents may be self-expanding or balloon expandable. Most of these devices are still undergoing development and modification and have not yet been shown to improve patency rates. More experience and long-term follow-up is required before their role can be properly assessed.

Embolization of pulmonary arterio-venous malformations

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Pulmonary arterio-venous malformations (PAVM) are uncommon, congenital communications between branches of the pulmonary artery and pulmonary vein. Their association with hereditary haemorrhagic telangiectasia (HHT) is well known; HHT is present in 36% of patients with single PAVM and 57% of those with multiple lesions. Fifteen per cent of patients with HHT will have PAVM. Patients with associated HHT appear to be more symptomatic, have a faster rate of progression and a higher complication rate. The complications of untreated PAVM are considerable and include hypoxaemia, polycythaemia, cerebrovascular accidents, brain abscess and haemothorax, which contribute towards an 11% mortality and 26% significant morbidity. It is for these reasons that treatment by embolization or surgical excision should be considered in all cases. Although the immediate mortality from excision of PAVMs (0–6%) is considerably less than that in untreated cases, percutaneous transcatheter embolization is now considered the treatment of choice, especially in patients with multiple lesions and those who are unfit for surgery. We present 19 patients with a total of 92 PAVMs treated by transcatheter steel coil embolization at a total of 34 embolization sessions. Embolization produced a considerable improvement in oxygen saturation at rest (mean increase 6.6%, $n = 12$), on maximal exercise (mean increase 9%, $n = 10$) and in the anatomical shunt (mean absolute decrease 15%, $n = 12$). The four most dramatic cases have shown absolute decreases in shunt of between 20 and 45%, with resolution of polycythaemia in two of these. Complications occurred in two patients, one of whom developed a deep vein thrombosis and the other a pulmonary infarct. In those patients who have undergone pulmonary angiography following previous embolization, none have shown recanalization of coils. It has previously been suggested that balloon embolotherapy is the most suitable method, because balloon placement, inflation and detachment can be precisely controlled. Our results, however, show that coil embolization is an effective and safe alternative to balloon embolization in the treatment of pulmonary arterio-venous malformations.

Modern interventional techniques in the biliary system including lithotripsy

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Many of the most recent innovations in biliary interventional radiology relate to the gallbladder and particularly to the non-surgical management of gallstones. Extracorporeal shockwave lithotripsy (ESWL) is now well established in the treatment of renal stones but it is only with the advent of second-generation lithotripters which use ultrasound for localization that the technique has been applied to fragmenting gallstones. Patients suitable for ESWL are those with three or fewer cholesterol stones greater than 1 cm in diameter in a functioning gallbladder. The treatment is a painless outpatient procedure but adjuvant oral bile-acid therapy is required to dissolve the resulting fragments. Total treatment is of the order of 6–12 months. For patients with multiple cholesterol stones in a functioning gallbladder, percutaneous cholecystostomy followed by contact dissolution with methyl tert-butyl ether (MTBE) is an option. Using a transhepatic route, the gallbladder is cannulated under ultrasonic and/or fluoroscopic guidance. The MTBE infusion lasts several hours and the whole procedure requires an inpatient stay of 48–72 h. Percutaneous cholecystolithotomy is a procedure entirely analogous to percutaneous nephrolithotomy. Using a transperitoneal approach the gallbladder is cannulated under general anaesthetic and the track dilated to enable stones to be removed mechanically via a cholecystoscope. Percutaneous cholecystostomy alone is increasingly used in the treatment of empyema and acute cholecystitis (especially the acalculous variety). Percutaneous removal of associated stones can be carried out as a delayed procedure. Obstruction remains the most common problem in the biliary tree with which the interventional radiologist is faced. In an effort to overcome the problems of stents becoming blocked or migrating new materials and stent configurations are constantly being evaluated. Early results with expandable metallic stents for benign strictures are promising.

Treatment of occlusive vascular disease with contact sapphire-modified Nd-YAG laser energy

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Continuous-wave Nd-YAG energy at powers of 10–15 W for 1 s in repeated doses was used to attempt to re-open eight occluded femoral arteries in six patients. The laser energy was modified by a rounded sapphire placed at the end of the fibre allowing for focusing of the laser beam and transmission of 60–80% of the energy, depending on the type of sapphire used. This technique was successful in re-opening five of the occluded arteries with occlusions of 2–20 cm in length. One perforation occurred, and in the remaining two arteries the laser caused a minor degree of dissection and the procedure was discontinued. No adverse effects were observed from either perforation or dissection. Percutaneous angioscopy was performed in four procedures demonstrating that the laser system was able to ablate atheroma as well as thrombus. The treated intima appeared to be white with only occasional charred deposits at the sites of prolonged laser use. The procedure was painless when the laser was fired within the arterial lumen. Pain did occur with dissection and is a reliable symptom to discontinue the procedure. We conclude that contact sapphire laser angioplasty is a promising and apparently safe procedure in peripheral vessels.

A bolt from the blue: sapphire-tipped pulsed laser angioplasty. I: Physical principles

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Laser energy delivered through a fibreoptic cable can vaporize atheroma and thus be used to cut a channel through an obstructed artery. Exposing tissue to laser energy produces a lesion with three zones, a zone of ablation where tissue is vaporized, surrounded by a zone of charred tissue, and around this an area of damaged tissue. Pulsed lasers produce less charring and surrounding damage than continuous-wave lasers if the pulse length is short compared with the thermal relaxation time of the exposed tissue, as there is then little dissipation of energy and therefore minimal thermal effects on surrounding tissue. We have shown that a laser using short trains of 100 μs pulses of 1064 nm wavelength produces less thermal damage and has some selectivity for atheroma. The simplest delivery system consists of a bare optical fibre, but this has a high incidence of perforation. The largest clinical experience has been with metal-tip fibres in which all the laser energy is converted to heat. This causes charring and thermal damage to surrounding tissue. We have shown that a sapphire-tipped fibreoptic device is advantageous because it transmits the majority of the laser energy as light rather than heat without the perforation risk of a bare fibre and with considerably less charring than a metal tip.

A bolt from the blue: sapphire-tipped pulsed laser angioplasty. II: Clinical results

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Experimental work has shown that use of a pulsed laser with a transparent device can produce ablation with minimum of surrounding damage and debris formation. Forty laser angioplasty procedures have been performed using energy from a pulsed Nd-Yag laser (Lumonics, UK), delivering near infrared light (1064 nm) in 100 μm pulses of approximately 300 mJ per pulse, directly through a transparent sapphire-tipped device.

All patients had symptoms severe enough to warrant surgery and all had occlusions of the superficial femoral artery with a mean length of 16 cm. Laser recanalization was followed by a balloon angioplasty in all cases. Thirty-seven legs of 34 patients were treated with an average of 60 J (range 10–235 J) with successful recanalization in 27 and immediate reocclusion in seven. Failed recanalization was due to poor transmission by the delivery device in the early part of the series (five cases), repeated passage of the device down a collateral branch (four cases) or dissection at the site of previous surgery (two cases). Immediate reocclusion was due to poor distal run-off (three cases) or technical difficulties with balloon dilatation (two cases). The 20 patients with successful recanalization obtained complete symptomatic relief and have been followed-up for up to 21 months (mean 8 months) with only one late occlusion at 5 months. The results shows that a pulsed laser and transparent device is successful in recanalization of peripheral arteries. The above results, with up-to-date figures, are presented.

The Bristol experience in lower limb angioplasty: complications in the first 500 cases

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Five hundred lower limb percutaneous transluminal angioplasties were performed on 370 patients at the Bristol Royal Infirmary in the period from October 1981 to July 1987. Fifty-one complications were seen in 45 cases, and were particularly prevalent in elderly patients. Complications included intimal dissection (22 cases), occlusion (8), haemorrhage (5), embolism (5), thrombosis (5), false aneurysm formation (1), and myocardial infarction (1). There were four deaths attributable directly or indirectly to the procedure. We analyse these results with particular reference to the age-related complications, and to the significance of antegrade or retrograde approaches to iliac and common femoral lesions.

The fate of patients having Gruntzig dilatation

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Life-table analysis of success rates of procedures such as femoro-popliteal grafts or Gruntzig dilatations gives a method of comparing series from different centres. It does not, however, show the effect of these procedures on the development of disease. We have followed-up 369 patients in whom a total of 502 Gruntzig dilatations for lower limb arterial disease were performed between 1980 and 1987. We report on the fate of these patients, looking in particular at the incidence of operation, re-dilatation, amputation and death. These findings have been related to the age, sex and presenting symptoms of the individual patients in order to investigate the place of Gruntzig dilatation in the spectrum of arteriosclerosis in an aging population.

Ten-year experience in percutaneous extraction of retained common bile duct stones

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During a 10-year period up to August 1988, 226 selected patients, age range 25–101 years (mean 61 years), were referred for percutaneous extraction of retained common bile duct stones following previous biliary surgery. The time interval to attempted extraction ranged from 4 to 30 weeks (mean 7 weeks). Percutaneous extraction using the steerable catheter technique as described by Burhenne was performed in 204 patients and was successful in 158 (77.5%). Twenty patients (10%) required more than two attempts to achieve removal of all the stones. Patients thought not suitable were those with narrow or tortuous tracks and large stones or with anterior tracks rather than the usual lateral or antero-lateral positions. The 22 non-treated patients and the 46 unsuccessful extractions underwent endoscopic sphincterotomy following which bile duct clearance was completed in all but three patients who eventually required further surgery. In-hospital follow-up was obtained in 153 patients (75%) and complications occurred in six. All patients settled on conservative management with no deaths. In conclusion, percutaneous extraction of retained common bile duct stones has a good success rate and low morbidity. The most suitable access is via a laterally placed straight track with T-tube at least 14 FG in size.

A strategy for the percutaneous removal of intrahepatic biliary calculi

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Intrahepatic calculi occur in a high proportion of patients with benign biliary strictures. They are often small and numerous. As a consequence of this, their removal using Dormia-type baskets or similar mechanical devices is difficult and time-consuming. Frequently, surgical removal is considered neither possible nor desirable, especially if previous biliary–enteric anastomoses have been made. We present our experience in the percutaneous removal of intrahepatic calculi in six patients. Three patients had more than one stone-removal procedure undertaken. Four patients had calculi in ducts above hepaticojejunostomy strictures and two patients had retained intrahepatic calculi after cholecystectomy. We describe the techniques employed and consider the relative usefulness of Dormia baskets, occlusion and angioplasty balloons and irrigation. The use of occlusion balloons in this situation has not been well described previously, but we have found them to be a very useful tool in difficult cases. We were able to remove all but three stones in our patients. No significant complications resulted. The procedures described are relatively simple, well tolerated and highly successful.

Reliability of percutaneous transhepatic cholangiography, endoscopic retrograde cholangiopancreatography and ultrasound in obstructive jaundice

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There has been a recent swing in the management of patients with malignant biliary obstruction towards stenting the biliary system endoscopically or percutaneously rather than undertaking surgery. Most of these patients undergoing stenting will not have surgical or pathological confirmation of their disease, therefore it is essential to know the accuracy of radiological and imaging investigations. The diagnostic value and usefulness of percutaneous transhepatic cholangiography (PTC), endoscopic retrograde cholangiopancreatography (ERCP) and ultrasound (US) of the upper abdomen in 172 jaundiced patients with a proven final diagnosis at surgery, histopathology or endoscopy (in the case of choledocholithiasis) was evaluated, based on the original interpretation of the results. Endoscopic retrograde cholangiopancreatography had a greater accuracy rate (84%) in comparison with PTC (78%) and US (50%). The successful ERCPs and satisfactory US scans were more frequently useful in determining the management of patients (75% and 72%, respectively) than successful PTCs (57%). However, the study showed that these investigations are not substitutes for each other as the procedures were considered essential in determining the management by assessors in 4% of US scans, 7% of PTCs and 15% of ERCPs. The study concludes that if US can reliably identify patients with distal common bile duct obstruction there seems to be little to be gained from invasive investigations if patients are undergoing surgery. All patients who have an unsatisfactory or inconclusive US scan should be investigated by ERCP or PTC when ERCP is contraindicated, failed or not available. Regardless of their accuracy, neither US nor direct cholangiography is without the possibility of error; misleading results were obtained in 10% of cases with US, 9% with PTC and 5% with ERCP. Therefore, it is mandatory to obtain a positive biopsy from the lesion in patients who are not undergoing surgery.

Stent changes in the palliation of malignant bile duct obstruction

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Percutaneous transhepatic endoprosthesis insertion for palliative decompression of malignant biliary obstruction is a recognized treatment, especially in patients with tumours that involve the confluence of the hepatic ducts at the hilum of the liver. The primary advantage of an indwelling stent over an external biliary drainage catheter is avoidance of the many major and minor complications associated with the latter technique. These include dislocations, bile leakage around the tube, cholangitis and patient discomfort. In addition, an external catheter is a daily reminder to the patient of his/her condition. Occlusion is the major complication of an indwelling endoprosthesis and several authors have suggested methods of unblocking or removing and replacing the occluded stent. There are several case reports of patients who have undergone such procedures. However, there is no published data on the complications associated with, and the palliation achieved in patients who have required multiple stent changes. We present 16 patients with proven malignant bile duct obstruction who have undergone a total of 30 stent change attempts (mean 1.9 per person, range 1–7), 28 of which have been successful (93%). The average duration of the initial stent was 29 weeks ($n = 16$) and of subsequent stents was 20 weeks ($n = 24$). Significant immediate complications were seen in only two patients (0.1%). One of these patients developed a perihepatic abscess following displacement of an external drainage catheter, in the other patient the stent could not be displaced and a replacement endoprosthesis could not be inserted. This patient therefore had to remain on external drainage. The palliation achieved in terms of jaundice, cholangitis and pruritus was good following 27 (96%) of the stent changes. Endoprosthesis insertion and repeated stent changes in malignant biliary obstruction achieves good palliation in most patients and avoids an external catheter with its associated morbidity and discomfort.

Mayneord Lecture

The new anatomy: a radiological renaissance

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Dramatic advances in imaging technology now permit the display of anatomical relationships with unprecedented accuracy. Such capability demands of the radiologist an equal improvement in interpretive skill. To be useful, the modern radiologist must be familiar with the diverse operative approaches to a lesion, with the specific approaches favoured by each individual neurosurgeon who refers cases, with the anatomical and medical factors that influence the choice of one approach over another, and with the anatomical variations that present potential dangers in undertaking a specific approach. The imaging study must be performed in such a fashion as to provide the data that will determine choice of one or other approach and to map out for the surgeon those difficulties that will be encountered en route. For intracranial lesions, any features of a lesion that will permit or prevent easy control of scalp haemorrhage and easy or difficult removal of the calvarial flap must be demonstrated. One must determine the need for and feasibility of control of intracranial pressure by ventriculostomy or cyst aspiration prior to opening dura and the presence of any significant surface veins near to the operative site, the sacrifice of which may increase the risk of developing post-operative cerebral oedema. It is also necessary to ascertain whether the lesion will present at the surface of the cortex allowing easy access, whether it lies x mm deep to the cortex, or whether it is likely to be impalpable and require intraoperative sonography to localize. The following should also be displayed: (a) the relation of the deep surface of the lesion to the ventricle and any potential for inadvertent entry into the ventricle; (b) the location of the vascular pedicle and adjacent important uninvolved vessels with respect to the planned surgical approach; (c) any potential for avulsion of the choroid plexus during lesion extirpation; (d) any multilocular cysts; (e) any "daughter" lesions to be sought; (f) precise anatomical landmarks to indicate when lesion excision is complete; and (g) any factors influencing the likelihood of post-operative extra cerebral fluid collections, pseudomeningoceles, etc. In the spine, the radiologist must have similar understanding of the differing positions of the cervical and lumbar nerve roots with respect to the structures bordering the neural foramina, so surgeons may choose the proper level for intervention and may elect to approach the disc herniation(s) via unilateral hemilaminotomies, bilateral laminectomies or lateral fascetectomies. Appreciation of the extent and (partial) septation of syringomyelia, including the dynamics of CSF pulsation within the syrinx and at the foramen magnum, is necessary, since these influence the extent of the lesion and the choice of therapy. The planes along which infection and tumour spread should also be appreciated to interpret successfully their diverse and occasionally confusing manifestations. This paper shows specific cases in which informed interpretation of the anatomical information available from imaging studies proved vital to patient management. In each case, photographs obtained at surgery, or unfortunate post-mortem examination, show the exact location of the lesion and provide detailed operating theatre experience, so that future cases may be interpreted more successfully.

Dysphagia

Chairman: Dr D. Nolan

Examining the dysphagic patient
B. Jones
The abnormal swallow
B. Jones
Endosonography of the oesophagus
W. R. Lees

Examining the dysphagic patient

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Dysphagia is a common symptom, which needs to be thoroughly investigated. Radiographic examination is ideal as it can evaluate both structure and function. Examination of the dysphagic patient depends on two major factors: meticulous attention to the examination itself (Jones & Donner, 1988) and an in-depth knowledge of normal and abnormal anatomy and physiology of swallowing (Donner et al, 1985). There are several important principles. (1) All structures involved in swallowing (lips, tongue, palate, pharynx, larynx, and oesophagus) should be evaluated as referred symptoms are common. (2) If possible, the examination should be biphasic. It should include both dynamic recording (cineradiography or videofluoroscopy) for motility and double-contrast examination for mucosal detail. (3) Each patient should be examined in both the erect and recumbent positions. The pharynx is best evaluated with the patient in the upright lateral and frontal positions, although semisupine views (obtained with a cross-table tube, if possible) will suffice if the patient is unable to stand. Certain abnormalities, however, (such as a Schatzki ring) may be evident only in the prone oblique position with the oesophagus distended. (4) Each patient with dysphagia is different. Although there is a routine or basic examination, as with any radiological technique, studies of patients with swallowing problems lend themselves to tailoring. Each examination is subtly altered on the basis of a mini patient history.

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The abnormal swallow

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Swallowing consists of oral, pharyngeal and oesophageal phases. (1) Oral: "leakage" of bolus into the oropharynx is prevented by apposition of soft palate and posterior tongue. Decompensation causes leakage into the oropharynx prior to swallowing, allowing aspiration into the open, unprotected larynx. (2) Pharyngeal: as bolus is propelled into the oropharynx by the tongue, the soft palate elevates to prevent nasal regurgitation. Progressive constrictor contraction propels the bolus onward. Pharyngeal peristalsis may be altered by muscular disease, neuromuscular disease or focal factors such as fibrosis. Respiration is suspended during swallowing. Retained bolus may be aspirated into the larynx during the post-swallow inspiration. The larynx moves upwards and forwards and closes, and the epiglottis tilts to cover the laryngeal aditus and deflect the bolus into the lateral food channels. The cricopharyngeus must relax and open completely to allow unimpeded passage of bolus. Several factors contribute to opening of the pharyngo-oesophageal segment: cricopharyngeal relaxation, anterior and upward movement of the larynx, pharyngeal contraction and the bolus itself. (3) Finally, oesophageal peristalsis propels the bolus into the stomach. There is a reserve capacity in swallowing allowing one structure to compensate for deficiency in an adjacent structure. These compensatory changes can be observed on the dynamic imaging study and indicate that swallowing is already compromised. Overt signs of decompensation include nasal regurgitation and aspiration.

Endosonography of the oesophagus

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Abstract not received.

Gastrointestinal Tract: proffered papers and posters

Chairman: Prof. G. M. Roberts

Late presentation of traumatic diaphragmatic hernia
K. McHugh, B. C. Ogilvie and F. J. Brunton
Gastric antral diaphragms: a review of 26 cases
S. G. Cooke and J. Virjee
Hypodense peripheral computed tomographic changes in hepatic tumours
A. Adam
Transient heterogeneity of the liver during contrast-enhanced dynamic computed tomography: histological correlation
U. Patel, A. Gholkar and D. F. Martin
Comparative value of computed tomography and ultrasound in the diagnosis of hilar cholangiocarcinoma
M. E. Roddie, E. Y. C. Yeung, P. McCarthy, R. H. Gompertz, I. S. Benjamin and A. Adam
Cholangiography: a comparative study of chronic pancreatitis and pancreatic carcinoma
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Computed tomographic scanning in pancreatitis: is ultrasound still necessary?
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Evaluation of computed tomography and ultrasound in detection of extrapancreatic abscess in severe acute pancreatitis
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Occult rectal intussusception: a radiological diagnosis
F. W. Poon, J. C. Lauder and I. G. Finlay
Outlet obstruction constipation and faecal incontinence: the role of videoproctography
J. C. Lauder, F. W. Poon and I. G. Finlay

Late presentation of traumatic diaphragmatic hernia

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Late presentation is thought to occur in 5–30% of diaphragmatic ruptures. Nine cases of delayed presentation of a ruptured diaphragm following blunt abdominal and/or chest trauma are presented. Six patients were male, and the age range was 21 to 81 years. Late presentation of diaphragmatic herniation varies from 1 to 16 years following the initial injury. Seven patients had been injured in road traffic accidents and the mean age of this group was 35 years. Two older patients (aged 61 and 81 years) had suffered injuries falling from a height in the year prior to presentation. Five of the nine were known to have fractured ribs at the time of the initial injury. Two had had surgery at this time but in only one of these had a diaphragmatic tear been identified. This was repaired but broke down 3 years later. Presenting complaints at late presentation included left chest and epigastric pain, recent-onset dyspnoea, intractable hiccough and gurgling noises in the left side of the chest. Two diaphragmatic ruptures were right-sided. Barium contrast examinations were used in six patients to confirm the diagnosis (five barium meals, one barium enema). A history of preceding chest or abdominal injury may not be available at the time of late presentation, or the patient may have forgotten the event. Occasionally the only abnormality visible on a chest radiograph may be an apparent elevation of the hemi-diaphragm. Ultrasound or barium studies are usually helpful in making the diagnosis. Delay in making the diagnosis may lead to serious complications.

Gastric antral diaphragms: a review of 26 cases

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Gastric antral diaphragms vary from small mucosal webs to almost complete diaphragms which can cause gastric outlet obstruction. They usually lie close to the pylorus and demarcate the distal antrum into a third small chamber between duodenal bulb and gastric lumen. Associated gastric ulceration is described in up to 50% of reported cases. We describe the radiographic features of 26 adult patients with gastric antral diaphragms diagnosed on barium meal. Fifteen patients were found to have gastric antral diaphragms only, there being radiological evidence of gastric or peptic ulceration in the remaining 11. Repeat barium examination confirmed the findings in six patients and endoscopic correlation was available in a further seven patients. In seven out of nine patients with radiographic evidence of erosive gastritis, the abnormality was limited to the antral mucosa distal to the diaphragm. Diaphragms were associated with ulceration and pseudopolyp formation in two cases each. No case of gastric outlet obstruction was found. Poor mucosal coating with barium in the antrum was seen in two patients sufficient to cause difficulty in radiographic interpretation. We conclude that the majority of antral diaphragms are not associated with frank peptic ulceration but that localized gastritis is a common feature. We hypothesize that when gastric erosion or ulceration occurs in patients with antral diaphragms, the site of abnormality is more likely to be distal to the diaphragm because of localized mechanical and physiological causes.

Hypodense peripheral computed tomographic changes in hepatic tumours

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Patients with malignant tumours limited to one lobe of the liver are sometimes considered for partial hepatic resection. Some of these patients have peripheral, low-attenuation areas within the tumour on computed tomography (CT), raising the question of invasion of adjacent tissues. A radiological/pathological correlation was carried out on 22 patients with metastases from colorectal or breast adenocarcinoma and 14 patients with primary hepatocellular carcinoma (HCC). Resection of the tumour was performed within 10 days of computed tomography and the specimen was perfused and fixed using specially designed apparatus, resulting in restoration to its *in vivo* size and shape. The resected liver tissue was then sectioned using a polypropylene frame with guide-slots which permitted sectioning at the 8 mm intervals used in CT scanning. The pathological sections were matched with the corresponding CT images. Eleven of the 22 patients with metastatic adenocarcinoma had a leaf-like, peripheral hypodense lesion. Pathological examination showed that this is produced by a thickened capsule and fibrosis with no evidence of extrahepatic invasion by the tumour. One of the primary hepatocellular carcinomas showed peripheral hypodense changes but these did not have the characteristic appearance of the leaf-like lesion on CT, and pathological examination showed that these changes represented areas of tumour necrosis. The leaf-like change is probably limited to metastases, does not represent extrahepatic invasion and should not be considered a contraindication to partial resection.

Transient heterogeneity of the liver during contrast-enhanced dynamic computed tomography: histological correlation

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Hepatic heterogeneity during contrast-enhanced dynamic computed tomography (CT) occurs in the presence of mass lesions but may also occur transiently on an otherwise normal examination and may not be considered pathological. In studying the significance of heterogeneity on hepatic CT, 71 consecutive examinations were reviewed. All patients had pre-contrast and contrast-enhanced dynamic CT. Review of the images revealed three groups. Twenty-one patients (30%) had normal examinations, 45 (63%) had abnormal scans because of mass lesions and five (7%) had normal scans, apart from transient heterogeneity during contrast enhancement which was either lobar or segmental. Correlation with subsequent investigation results showed that 20 of the 21 patients with normal scans had no liver pathology but one patient had chronic active hepatitis. Forty-five patients with abnormal scans had a variety of pathologies, from benign cysts to malignant tumours. In the group of five patients with transient heterogeneity only, all had histologically proven disease, four revealing nodular regeneration, which was associated with disruption of the normal hepatic vasculature, presumably leading to shunting of the blood/contrast mixture, a phenomenon described in hepatic mass lesions. Dynamic contrast-enhanced hepatic CT which reveals transient heterogeneity as the sole abnormality is highly suggestive of underlying disease and all such patients should undergo further clinical and radiological evaluation.

Comparative value of computed tomography and ultrasound in the diagnosis of hilar cholangiocarcinoma

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Cholangiocarcinoma arising at the liver hilum is a rare but potentially resectable tumour, usually presenting with jaundice of insidious onset and progressive severity. The tumour is characteristically small and differentiation from other causes of hilar obstruction such as secondary tumours, sclerosing cholangitis and benign strictures can be difficult. In the past, the diagnosis was often made by inference, but recent advances in imaging have now made it possible to differentiate high bile duct carcinomas from other causes of obstructive jaundice. We present 42 patients with hilar cholangiocarcinoma who presented between 1984 and 1988. The diagnosis was confirmed by histology in 32 patients and by clinical and radiological evidence in 10 patients. All 42 patients underwent computed tomography (CT) and 33 of these had ultrasound (US) examinations. A hilar mass was demonstrated by US in 88% of patients and in only 26% by CT. The smallest mass detected by ultrasound measured 1 cm in diameter and the smallest detected by CT measured 2 cm. Those masses demonstrated by CT were typically ill defined, of low attenuation and did not enhance following intravenous contrast medium. The relative merits of CT and US were compared in assessment of bile duct involvement and in detection of liver metastases, portal lymphadenopathy and lobar atrophy. Ultrasound proved superior in assessment of duct involvement and CT proved superior in detection of lobar atrophy. Both methods were equally effective in detecting liver metastases and portal lymphadenopathy. We conclude that US remains the method of first choice in the diagnosis of hilar cholangiocarcinoma. However, the CT appearance of the mass, when seen, is characteristic and lobar atrophy, which is suggestive of hilar cholangiocarcinoma, cannot be reliably detected by US or by percutaneous transhepatic cholangiography. Computed tomography is therefore an important investigation in assessment of the patient for surgery.

Cholangiography: a comparative study of chronic pancreatitis and pancreatic carcinoma

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Differentiation of pancreatic carcinoma from chronic pancreatitis remains difficult, even at laparotomy and when wedge-resection biopsies are submitted for frozen-section evaluation. Attempts to aid differentiation pre-operatively have centred on the radiological appearance of the pancreatic duct and pancreatic function tests. Although many studies have provided a detailed description and classification of cholangiographic features in both chronic pancreatitis and pancreatic carcinoma, a specific study of the cholangiographic differentiation between pancreatitis and cancer with sufficient numbers of patients has not been reported. Cholangiograms of 47 patients with chronic pancreatitis and 53 patients with pancreatic carcinoma, jaundiced or not, were classified according to the original classification of Caroli, and the liver function tests were then correlated. The study demonstrated significant differences between chronic pancreatitis and pancreatic carcinoma patients in the following points: (i) the chronic pancreatitis patients were younger, (ii) pancreatic calcifications on plain radiographs were seen only in chronic pancreatitis patients, (iii) the mean maximum diameters of the intra- and extrahepatic biliary ducts were greater in patients with pancreatic carcinoma, (iv) the cholangiograms were abnormal in 64% of the patients with chronic pancreatitis (these included 67% Type I, 3% Type II, 10% Type III, 10% Type IV and 3% Type V stricture, while 17% of patients had biliary abnormalities which could not fit Caroli's classification) and in all patients with pancreatic carcinoma (these included 17% Type I, 7% Type II, 4% Type III, 66% Type V stricture, and 6% non-classified biliary abnormalities), (v) irregularity of stenosis was seen exclusively in patients with pancreatic carcinoma, and (vi) the mean values of the total serubilirubin, aspartate aminotransferase, alanine aminotransferase and alkaline phosphatase concentration were significantly higher in patients with pancreatic cancer.

Computed tomographic scanning for pancreatitis: is ultrasound still necessary?

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Patients with acute pancreatitis are currently examined by contrast-enhanced CT scanning within 48 h of admission to this institution. Ultrasound often does not visualize the pancreas in acute pancreatitis and both clinician and radiologist might consider ultrasound unnecessary where CT has already been performed. Twenty-six consecutive patients with acute pancreatitis underwent CT of the upper abdomen (9 mm contiguous slices) and contrast-enhanced CT of the pancreas (9 mm slices at a single level). Nineteen of these patients were also examined by ultrasound. The gallbladder was identified in 25 cases by CT and stones were identified in the gallbladder in six of these. In all these cases biliary disease was considered to be the cause of pancreatitis. However, CT failed to identify gallbladder stones in five cases which were subsequently identified by ultrasound. Biliary disease was considered to be the cause of pancreatitis in four of these cases and a possibility in the fifth case. Obstructive liver tests were present in only four cases, one of whom had alcoholic pancreatitis. The liver tests in patients with a biliary aetiology for pancreatitis suggested hepatitis in two cases, biliary disease in three cases and were not discriminating in five cases. Patients with acute pancreatitis should continue to have an ultrasound examination to exclude a biliary cause even if the CT scan does not show gallbladder stones and the liver tests do not suggest biliary tract disease. The result may influence immediate and long-term management of the patient.

Evaluation of computed tomography and ultrasound in detection of extrapancreatic abscess in severe acute pancreatitis

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The literature contains many recommendations concerning the use of computed tomography (CT) versus ultrasound (US) in acute pancreatitis. We retrospectively reviewed US and CT in seven patients with severe acute pancreatitis and clinical suspicion of an abscess. We wished to determine if CT often demonstrated significant pathology not visualized by US in these patients. All CT examinations showed significant pathology not visualized by US (typically extrapancreatic fluid collections). Subsequently we have reviewed US and CT examinations on three further patients with acute pancreatitis. In these patients CT scanning again demonstrated significant complications of pancreatitis not visualized by ultrasound. In all patients in this study, US studies were performed by radiologists with very extensive experience in abdominal ultrasound. Frequently, patients with severe acute pancreatitis will have gastric and bowel distension. These patients may be very ill and have had recent surgery. Thus there may be a large abdominal wound with drains and dressings obscuring adequate visualization on US. All or some of these factors may combine to give a suboptimal or technically difficult US examination. We noted that even when US was reported as giving satisfactory visualization of the pancreas and surrounding area, CT still demonstrated significant extrapancreatic collections not seen on US. Abscess formation if not treated quickly carries a high mortality in patients with acute pancreatitis. Thus we feel that CT is essential in this highly select small group of patients with severe acute pancreatitis and our findings from this study are presented.

Small bowel enema audit

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A retrospective audit was performed on 361 patients attending for small bowel enema examination between January 1982 and January 1986. Seventeen examinations were unsuccessful, the usual cause being failure to intubate the small bowel satisfactorily. The period of follow-up following a successful examination ranged from 16 to 76 months. The incidence of small bowel disease in this series was 17% with an overall sensitivity of 95% and a specificity of 97%. In the diagnosis of Crohn's disease ($n = 38$) the sensitivity and specificity were 100% and the length of bowel involvement as determined by the small bowel enema correlated well with subsequent surgical and pathological measurements. There were three false positive results leading to two negative laparotomies in the diagnosis of adhesions ($n = 13$, sensitivity 70%, specificity 95%). These false positives all showed crowding of small bowel loops in the pelvis and so this is felt to be an unreliable sign. There were five cases of coeliac disease, four correctly diagnosed and one false negative. A Meckel's diverticulum was correctly diagnosed in three patients with one known false negative. Diagnostic errors were shown to arise chiefly from inadequate analysis of radiological signs. The accuracy of clinical examination by physician or surgeon was approximately 50%, physicians tending to overdiagnose Crohn's disease and malabsorption and surgeons overdiagnosing Crohn's disease and adhesions. There was a high diagnostic yield for the examination if there was a previous history of small bowel disease or large volume diarrhoea with high fat content, and a good yield with colic, distension, weight loss and diarrhoea. Vague pain with minimal localizing signs resulted in a very low yield.

The value of ^{75}Se homocholic acid taurine retention in the investigation of small bowel disease

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^{75}Se homocholic acid taurine (SeHCAT), a bile salt analogue, is available for assessment of terminal ileal function. Seven days after an oral dose of 370 kBq, whole-body activity (γ radiation) is measured. This is expressed as a percentage of that measured on day 1. Retention of less than 8% signifies bile salt malabsorption, greater than 15% is normal and 8–15% is equivocal. We are currently reviewing all SeHCAT retention scans performed in our department. Twenty-seven cases have been analysed, although many more will soon be available as the test is popular with the relevant clinicians. Nine patients had abnormal results (five cases of Crohn's disease and ileal resection, one of ileal resection alone and one of pharmacologically induced bile salt malabsorption). Fourteen patients had normal SeHCAT retention. Eventual diagnoses were irritable bowel syndrome (10 cases), alactasia, pernicious anaemia and Crohn's disease (two cases). Four patients had equivocal scans; three were thought to have irritable bowel syndrome. The fourth also has an abnormal Schilling test. It is concluded that the SeHCAT retention scan is a valuable, simple test in the investigation of small bowel problems, particularly in the context of Crohn's disease, previous surgery and biochemically demonstrable abnormalities.

Chronic intussusception, a rare cause of failure to thrive: the role of imaging

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Intussusception is usually recognized as a disease of infancy, most commonly with an acute presentation. Chronic intussusception represents 1% of cases under 1 year of age and 10% of those above. Presentation usually includes at least part of the triad of abdominal pain, a palpable mass or vomiting. Chronic intussusception is more commonly described in the tropics and Africa, where infestation is an important predisposing factor. We present a case of a 1-month-old male child who presented with failure to thrive. At the time of presentation a small bowel study was reported as normal and a full malabsorption screen was normal. Supportive therapy was initially given. After a further 10 weeks he represented with further weight loss as the predominant symptom. A right upper quadrant mass was palpated. Ultrasound demonstrated this to be a highly echogenic mass, most likely bowel associated, but without the characteristic features of an intussusception. Small bowel contrast studies demonstrated an intussusception of the ileo-colic region. Surgery and histology confirmed this to be chronic in nature. This interesting case illustrates the very rare presentation of chronic intussusception as failure to thrive. This has only been reported previously in two cases. As a potentially treatable cause of failure to thrive, we highlight the use of gastrointestinal contrast studies and ultrasound in aiding diagnosis.

Comparison of double-contrast barium enema with open-access flexible fibreoptic sigmoidoscopy

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In Bristol an open-access flexible fibreoptic sigmoidoscopic service has been established. The aim of this study was to compare the results of flexible sigmoidoscopy (done by committed colonoscopists) and double-contrast barium enema (DCBE) and to indicate if any change in policy should be instituted. Of 840 open-access flexible fibreoptic sigmoidoscopies performed, 366 had a DCBE. There were 40 proven carcinomas (4.8% incidence), 78 cases of polyps (9% incidence) and 11 non-malignant strictures (1.3%). It was found that DCBE was more accurate in the diagnosis of carcinoma (96% compared with 86% success of those reachable by the sigmoidoscope); DCBE was also more accurate in the diagnosis of strictures, correctly identifying all the strictures seen. Flexible sigmoidoscopy had a 50% false positive rate in diagnosing strictures. However, with polyps, although the true positive rate was similar to flexible sigmoidoscopy (88% compared with 90%), flexible sigmoidoscopy had a better false negative rate (0.5% compared with 3.3%). One patient suffered colonic perforation from flexible sigmoidoscopy whilst there were no documented complications of DCBE. In conclusion, DCBE is safer, faster, cheaper and more accurate than flexible sigmoidoscopy, and hence a DCBE is the investigation of choice. Colonoscopy would then be used for diagnostic biopsies in uncertain cases and following negative (normal) DCBE where clinical suspicion persists. This leaves an extremely questionable role for flexible sigmoidoscopy.

Radiological features of colonic lymphoma studied on barium enema examination

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Colonic involvement by lymphoma occurs in up to 24% of patients studied at autopsy yet is rarely diagnosed on barium enema examination. We have retrospectively reviewed patients with lymphoma involving the colon examined by barium enema in our department over the last 6 years. Details of patients were obtained from the departmental pathological register and by consultation with the oncology service. Five cases of lymphoma were examined with colorectal involvement. All patients had secondary disease from non-Hodgkin's lymphoma. Symptoms referrable to the bowel included diarrhoea, change in bowel habit, abdominal pain and weight loss. The radiographic features on barium enema examination were analysed in detail and are discussed. The important abnormalities comprised strictures (three cases), infiltrating plaques (two cases), multiple small nodular filling defects (two cases), extraluminal masses (two cases) and intraluminal mass (one case). The most frequent site of localized involvement was the recto-sigmoid, followed by the caecum and ascending colon except in the nodular variety when widespread involvement occurred. The distinction of strictures due to lymphoma and those due to carcinoma or other causes is important and is discussed. Using radiographic appearances alone this distinction may be difficult and can often only be made by histological analysis. Widespread nodular lymphoma involvement may be mistaken for colonic polyposis, one of the colitides or lymphoid nodular hyperplasia. Differentiation between these entities is possible on account of the characteristic appearance of the nodules in association with other features. During the period of study, 17 cases of lymphoid nodular hyperplasia involving the colon were also seen. The relevance of this condition is discussed and the radiographic features compared to the lymphoid nodular abnormality seen in colonic lymphoma.

Occult rectal intussusception: a radiological diagnosis

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Overt rectal intussusception is a common problem in the elderly, which is diagnosed clinically. There is increasing evidence that patients may have an occult partial prolapse of the mid-rectum (intussusception) which is not detected on clinical examination or barium enema. The patients may have symptoms of mucus discharge, tenesmus, soiling or incomplete evacuation. The anomaly may be identified using videoproctography. We have studied 150 patients with ano-rectal symptoms using videoproctography. The rectum was filled with 100 ml of thick liquid barium. Video recordings were made during defaecation and spot radiographs were taken in both lateral and AP positions. Of these, 16 (10.6%) patients (13 female, three male) were found to have rectal intussusception. Their symptoms include constipation (31%), incontinence (37%), proctalgia (25%), incomplete emptying (25%) and mucus discharge (12.5%). Four patients (25%) also had previous operations for haemorrhoids. Apart from rectal intussusception, five patients (31%) were found to have an anterior rectocoele, 10 (62%) had a degree of pelvic floor descent and one (6%) patient had puborectalis paradox. These data suggest that occult rectal intussusception may be more common than previously appreciated in patients with ano-rectal symptoms. Diagnosis is important since the anomaly can be successfully corrected by surgery.

Outlet obstruction constipation and faecal incontinence: the role of videoproctography

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Videoproctography is a dynamic study of ano-rectal function. It is of particular interest in the investigation of outlet obstruction constipation (OOC) and faecal incontinence. We report a series of 19 patients with OOC (Group 1) and 19 patients complaining of faecal incontinence (Group 2), using a combination of spot radiographs to measure ano-rectal junction descent from the pubococcygeal line and ano-rectal angles (basal = posterior rectal wall, axial = axis of rectum), both at rest and on straining, and videotape to record the dynamics of defaecation. Group 1 patients were female, age range 22–66 years, mean 45 years. Group 2 patients (four male, 15 female) had an age range 41–78 years, mean 59 years. The results in Group 1 gave a value for the ano-rectal junction of 0.79 ± 0.96 cm (mean ± SD) and on straining, 2.5 ± 1.37 cm ($p < 0.001$). The basal resting angle was 92.9 ± 10.0° and the straining angle 91.8 ± 9.3° (not significant). The equivalent axial angles were 118.6 ± 13.5° and 114.0 ± 15.3° ($p < 0.05$). Thus, the ano-rectal junction descent is significant, the axial angle less so and the basal angles are not significant. In Group 2 the resting ano-rectal junction was 1.0 ± 0.72 cm, and on straining was 2.7 ± 1.45 cm ($p < 0.001$). The resting basal angle was 105.3 ± 13.9° and on straining, 115.3 ± 10.5° ($p < 0.001$). The resting axial angle was 131.4 ± 10.8° and on straining was 135.3 ± 10.9° (not significant). In this group the important measurements are ano-rectal junction descent and basal angles. Comparing the two groups, ano-rectal junction descent is not significant but resting and straining basal and axial angles are ($p < 0.001$). We conclude that a non-opening basal angle occurs in OOC, whereas in patients with faecal incontinence there is a larger resting basal angle which opens on straining.

Neuroradiology: proffered papers and posters

Chairman: Dr W. St Claire Forbes

Phosphorus-31 magnetic resonance spectroscopy of the human brain using four-dimensional chemical shift imaging and phase mapping techniques
G. A. Coutts, I. J. Cox, D. G. Gadian, J. Sargentoni, D. J. Bryant and A. G. Collins
An assessment of the clinical potential of ultra-high-speed imaging of the brain by the echo planar technique
B. S. Worthington, M. K. Stehling, R. J. Ordidge, R. Coxon, A. M. Houseman, B. Chapman, R. Turner, J. L. Firth and P. Mansfield
A prospective comparison of gadolinium-enhanced magnetic resonance, T_2-weighted magnetic resonance and contrast-enhanced computed tomography in the detection and diagnosis of intracerebral metastases from small cell lung cancer
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Magnetic resonance changes of the neurohypophyseal axis associated with growth hormone deficiency
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The role of magnetic resonance imaging in the assessment of infection involving the spinal axis: an analysis of the spectrum of changes
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Lumbar disc disease: a comparative study between magnetic resonance imaging and discography
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Cerebral angiography performed with oral premedication alone: a trial of 40 patients
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Phosphorus-31 magnetic resonance spectroscopy of the human brain using four-dimensional chemical shift imaging and phase mapping techniques

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We are using four-dimensional chemical shift imaging (4D CSI) to map the phosphorus metabolites within the entire human head. We often observe only little, if any, abnormality in the spectra from pathological regions. This means that our technique must be optimized in order to detect small metabolic changes. We use proton imaging to locate pathology within the grid system. Phase maps are constructed from two images collected with different time delays to the centre of data collect. These maps represent variations in B_0 homogeneity and tissue susceptibility. A knowledge of such field variations is useful in analysing the spectroscopy data. The nominal spatial resolution of the spectroscopy data is 3–4 cm in each direction. With this resolution, a focal lesion must generally be greater than 4 cm in size in each direction (to reduce partial volume and voxel smearing effects) in order to obtain an indication of its metabolic profile. It is difficult to improve the spatial resolution within the timescale of a clinical examination, given that the T_1 values of the metabolites are long. The data sets obtained from controls using a nominal spatial resolution of 3–4 cm show that the spectral profile is uniform across the brain. In some brain tumours, particularly metastases, an increase in the peak area of phosphomonoester is observed.

An assessment of the clinical potential of ultra-high-speed imaging of the brain by the echo planar technique

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Shorter total examination time facilitating more rapid patient throughput, better patient tolerance and an opportunity to study in real-time flow phenomena in the vascular tree and CSF compartments are important benefits of ultra-high-speed brain imaging. Imaging was carried out at 0.52 T employing a low-inductance, actively screened coil system. High-quality transverse axial and coronal slices with a thickness of 5–10 mm were obtained with a true matrix display of 128 × 128 without the need for signal averaging. T_1-weighted images are obtained by inversion–recovery employing a 180° rectangular pulse for spin-inversion followed by collection of an echo planar image; choice of T_1 weighting is achieved by altering inversion time. T_2-weighted images were obtained employing the blipped echo planar single pulse technique (BEST) and modulus BEST where data acquisition times for a complete two-dimensional image is 64 ms and 128 ms, respectively. In BEST images a choice of T_2 weighting is obtained by adjustment of echo time while modulus BEST images have intrinsic T_2 weighting. A multislice technique has been developed which allows the collection of eight contiguous slices in 1.6 s. Studies from volunteers are used to illustrate the excellent discrimination that can be achieved between the grey and white matter as well as the brain and CSF pool. Studies from patients with a range of pathology are used to illustrate first, how abnormalities of CSF and blood flow can be demonstrated and secondly, how optimization of pulse sequences to achieve maximal conspicuity of particular features can be achieved simply and interactively by real-time adjustment of the pulse parameters.

A prospective comparison of gadolinium-enhanced magnetic resonance, T_2-weighted magnetic resonance and contrast-enhanced computed tomography in the detection and diagnosis of intracerebral metastases from small cell lung cancer

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The final results of a prospective study comparing the relative sensitivity of gadolinium (Gd)-enhanced magnetic resonance (MR), T_2-weighted MR and contrast-enhanced computed tomography (CT) in the detection of small asymptomatic brain metastases are presented. All patients had all three investigations repeated at 3-monthly intervals. A total of 109 examinations were carried out in 44 patients (30 male, 14 female) with a mean age of 66 years. On 93 out of 109 occasions (75%) the information from all three imaging modalities was identical (90 negative and three positive scans). There were nine patients in whom Gd-enhanced MR showed additional metastases when compared with CT and T_2-weighted MR. Four patients showed metastatic disease on two imaging modalities only (two each for CT/Gd and MR/Gd). Finally, three patients showed evidence of cerebral metastatic disease on Gd-enhanced MR only. Subsequent CT examinations confirmed the presence of metastases in CT-negative cases. Computed tomography showed a total of 48 lesions, T_2-weighted MR a total of 40, and Gd-enhanced MR demonstrated 132. All the additional lesions seen with Gd-enhanced MR were under 2 cm in diameter and 90% of them under 0.5 cm in diameter. From this we conclude that Gd-enhanced MR is the most sensitive method for detecting small intracerebral metastases.

Magnetic resonance-gated intracranial cerebrospinal fluid dynamics: evaluation of cerebrospinal fluid pulsatile flow

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A new method called magnetic resonance-gated intracranial cerebrospinal fluid (CSF) (liquour) dynamics (MR-GILD) is reported. Pulsatile flow in CSF pathways is revealed by the difference between diastolic and systolic gated images. The ventricles, cisterns and vascular structures are clearly demonstrated. The dependence of CSF movement on arterial pulse transformation was analysed. Illustrative cases are given to show some pathological variations. The use of MR-GILD for neurosurgical patients is discussed.

Reference

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Magnetic resonance changes of the neurohypophyseal axis associated with growth hormone deficiency

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Previous investigators have suggested that there are specific changes in the neurohypophyseal axis visualized on MRI in patients with primary growth hormone deficiency (Kelly et al, 1988). We have reviewed eight cases of growth failure ranging in age from 7 to 33 years (mean 15 years 9 months) associated with reduced levels of serum growth hormone or an impaired growth hormone response to glucose load. All patients were imaged at 1.5 T, with 3 mm contiguous T_1-weighted images in a coronal and sagittal plane. Measurements were obtained from the sagittal images. One patient had a large suprasellar mass compatible with craniopharyngioma. Of the remaining seven patients, six were judged to have small anterior lobes, the mean height of all seven being 3.5 ± 0.7 mm compared with a height of 5.3 ± 1.3 mm ($p = 0.05$) in a comparable group of 10 normal subjects. Five had normal signal intensity from the posterior lobe, one had a very small posterior lobe and one had an ectopic posterior lobe situated just posterior to the optic chiasm. Six out of seven had thin or absent pituitary stalks with only one subject with acquired growth hormone deficiency showing a normal calibre stalk. These findings indicate that there are typical features of growth hormone deficiency and that MRI is of value in their evaluation.

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An investigation of T_1 and T_2 values from magnetic resonance images of pituitary tumours

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Development of high-field magnetic resonance units has resulted in interest in the use of magnetic resonance for evaluation of pituitary tumours, particularly microadenomas, because thin sections in any plane can now be obtained. This, combined with microsurgical techniques and earlier diagnosis of hyperprolactinaemic states, means that the precise identification of the site of the tumour has become important. Previous reports have suggested that tumours are usually hypo- or isointense on T_1-weighted images but of variable intensity with T_2 weighting. A ratio analysis of T_1 and T_2 values in large pituitary tumours compared with adjacent white matter has been carried out on 3 and 5 mm coronal images at 1.5 T. Ten patients with prolactin secreting tumours and five patients with growth hormone secreting tumours were studied and compared with five patients with no known pituitary pathology. Although the tumours were frequently visible separate from adjacent pituitary tissue, no significant difference was found between the tumour/white matter ratio and the pituitary/white matter ratio in normals for either T_1- or T_2-weighted images. These preliminary findings suggest that ratio analysis is of no value and it may be necessary to obtain T_1 and T_2 maps for quantitative analysis of small pituitary tumours.

Pituitary imaging: is contrast medium necessary?

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Examination of the pituitary gland by computed tomography in patients with a suspected prolactinoma is usually performed following intravenous contrast medium. Abnormalities are found infrequently and have doubtful clinical significance. The aim of this paper is to assess whether the pituitary and suprasellar structures can be visualized satisfactorily without intravenous contrast medium. Twenty-five consecutive patients referred for investigation of hyperprolactinaemia were examined by direct coronal computed tomography before and after intravenous contrast medium. The images were viewed by two independent observers to assess the pituitary height, width and contour, and the visibility of the infundibulum, hypothalamus and chiasm. The presence and size of a possible tumour was recorded. The inter- and intraobserver measurements were compared using ANOVA and *t*-test. There was no significant difference between the means ($p = 0.05$). The qualitative observations were compared using kappa. Infundibulum assessment was at best moderate (0.4) with little improvement following contrast medium. Chiasm visibility increased after contrast medium (0.6 to 0.9) but the effect was inconsistent. The hypothalamus and the pituitary contour were well demonstrated before and after contrast medium. In only one case was a possible tumour identified by one observer on both the pre- and post-contrast-medium images, there being no agreement in the remainder. These findings suggest that an unenhanced examination of the pituitary is adequate in moderate hyperprolactinaemia.

The role of magnetic resonance imaging and computed tomography in the evaluation and management of chordomas and clival-based tumours

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Seven patients with chordomas involving the clivus or upper cervical region were examined by magnetic resonance imaging (MRI). The signal characteristics of the former were compared with those of seven other clival-based tumours, which included metastatic adenocarcinoma, meningiomas and invasive pituitary adenomas. The information obtained from MRI was compared, where available, with the results of computed tomographic scans. The lack of planar restriction and obtrusive artefact from bone and air containing structures within the skull base proved to be important advantages of MRI. This was shown in the better delineation of the anatomical limits of the tumour. The sagittal plane was optimal for defining upward extension into the suprasellar region, inferior extension into the upper cervical region and posterior encroachment on the brain stem and cervical cord, whereas the coronal and transverse axial plane gave optimal demonstration of parasellar extension with vascular encasement. Computed tomography was superior in the demonstration of tumour calcification and bone destruction. Apart from the meningiomas, which showed only moderate lengthening of relaxation times, the signal characteristics did not provide any reliable distinguishing features. One of the chordomas that was examined after intravenous administration of Gd-DTPA showed pronounced enhancement. The clival chordomas were treated with radiotherapy; the two involving the upper cervical region were managed by operative debulking with a combined ENT, orthopaedic and neurosurgical approach in two stages. First, tumour debulking was carried out from behind, followed by a spinal fixation using Luque rods. At a later operation anterior spinal decompression was carried out by the transoral route. In these patients, sequential MRI proved informative in planning the surgical approach, even though there was some local degradation of the image because of the metallic implants. We conclude that MRI is useful in the assessment of chordomas and other tumours of the clivus and is particularly helpful to the surgeon attempting operative removal.

The role of magnetic resonance imaging in the assessment of infection involving the spinal axis: an analysis of the spectrum of changes

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It has been demonstrated in an animal model (33 rabbits) that the earliest change in disc space infection is a loss of signal from the disc on T_2-weighted images and the short tau inversion–recovery (STIR) sequence (Worthington et al, 1987). This is rapidly followed by the development of a zone of high signal adjacent to the discovertebral junction and eventually the disc space itself develops a high signal as it becomes occupied by granulation tissue. The efficacy of magnetic resonance imaging (MRI) in diagnosing disc space infection was compared with that of plain radiographs and scintiscanning with technetium-99m methylene diphosphonate. In well established infection MRI showed a sensitivity of 92.5%, a specificity of 96.5% and an accuracy of 95%. Bone scans had a sensitivity of 41%, specificity of 93% and accuracy of 68%. Plain radiographs had a sensitivity of 81.5%, specificity of 93% and accuracy of 87.5%. The appearances on MRI of discitis preceded the changes on scintigraphy and plain radiographs by several days. Clinical examples of discitis in children and osteomyelitis of the spine in adults are used to illustrate the spectrum of MRI appearances. Spinal epidural abscess is uncommon but early diagnosis and treatment is essential to avoid irreversible neurological sequelae. Magnetic resonance imaging of the spine employing appropriately T_2-weighted spin–echo sequences can readily localize the size and extent of a collection and in three recent cases obviated the need for myelography. The STIR sequence is particularly valuable in demonstrating any associated osteomyelitis and spread of infection into the paravertebral soft tissues.

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Lumbar disc disease: a comparative study between magnetic resonance imaging and discography

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The clinical utility and advantages of magnetic resonance imaging (MRI) in discogenic disease of the lumbar spine are described. Some authors now feel that discography should be abandoned pre-operatively (Gibson et al, 1986), while others have recently demonstrated that it still has a valuable role (Colhoun et al, 1988). Twenty patients with persistent lumbar pain considered to be discogenic in origin underwent MRI on a 1.5 T superconducting system (Siemens Magnetom) using a spine receiver coil. Contiguous 5 mm sections in the sagittal plane were obtained. Abnormalities were confirmed on trans-axial sections. T_1 (500/28) and T_2 (1000/80) weighted spin–echo sequences as well as a limited flip angle gradient echo sequence (Flash 40) were employed. Following MRI, discography was performed and the results assessed independently. Of the 51 discs examined by both methods, the results correlated in 48 (95%). Discrepancies occurred in three discs, all of which were normal on MRI but mildly degenerate on discography. All three were non-symptomatic. Positive signs were elicited on discography in seven patients; MRI accurately identified the symptomatic level in all cases. Disease was shown at additional levels on MRI in six patients; of these, three had disease at L5/S1 where there was failure at discography to inject the disc, two had generalized disc disease affecting all lumbar vertebrae, and one showed an incidental finding of spinal stenosis. In those patients with multi-level disc disease on MRI (13) it was not possible to identify a symptomatic level in four. This study shows that both modalities have a role in the detection and assessment of the degenerate disc. Magnetic resonance imaging is the investigation of choice, discography being reserved for those with multi-level disc disease in whom it is not possible to identify the symptomatic level.

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Asymptomatic disc disease: a possible anatomical explanation

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Significant disc protrusions may be seen at the lumbosacral level in patients who have few abnormal clinical signs. One reason for this observation may be the variation in the normal anatomy of the S1 nerve. We have reviewed the computed tomographic examinations of 25 patients who have normal appearances in the lumbosacral region to determine the level at which the S1 nerve root sheaths are first identified. The point of origin of the S1 nerve root sheath was taken to be the level at which the contour of the theca changed from a round or elliptical shape to a triangular shape. Typically the S1 root sheaths were seen on the next caudal image as separate structures. The cranio-caudal distance from the point of origin to the level of the lumbosacral disc was recorded. The position of the S1 root sheath within the lateral recess was recorded according to its relationship to the facet joint. In 14 of the 25 patients (56%) the S1 root sheaths arose cranial to the disc (mean 7 mm, range 3–18 mm). In nine patients (36%) the point of origin was at disc level, and in two patients (8%) the S1 root sheaths were not identified until caudal to the disc. In six of the 14 patients in whom the S1 root sheaths arose cranial to the disc, the sheaths were laterally placed in the lateral recess. It is possible that patients with this latter anatomical arrangement would be especially likely to suffer S1 root involvement by the common disc and facet joint degenerative processes. Conversely, only large caudally directed disc protrusions could impinge on the short intraspinal S1 nerves in the small minority of patients in whom the sheaths arise caudal to the disc.

Outpatient lumbar radiculography: comparison of iopamidol and iohexol

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A potential source of savings to the health service is increasing the proportion of investigations performed on an outpatient basis. Our initial study on 200 patients undergoing lumbar radiculography, presented at Radiology '88, demonstrated that outpatient radiculography could be performed safely with 10 ml iohexol (240 mg/ml) (Omnipaque, Nycomed). The purpose of this consecutive study, identical in design, is to measure the same parameters following radiculography with iopamidol (Niopam, Bracco) in outpatient and inpatient control groups and compare the results with those of the iohexol series. One hundred and thirty-two outpatients and 129 inpatients were entered into the study and given a series of four questionnaires to complete (before, 4 h, 24 h and 1 week following the examination). In order that the overall quantity of iodine introduced should be comparable, 12 ml iopamidol (200 mg/ml) was injected. Following the examination the outpatients were observed for 4 h before being allowed home and the inpatients were kept in hospital for a minimum of 24 h. In the iopamidol group, as in the iohexol study, no statistically significant difference in the incidence and severity of side-effects was found between the respective outpatient and inpatient groups. In comparing the iopamidol and iohexol series no statistically significant differences were demonstrated 4 or 24 h after the examination. In the period between 24 h and 1 week the incidence and severity of headache, nausea and dizziness were all significantly greater in the iopamidol group, as was the duration of the headache in these patients. Of those patients with a headache, a duration of 1 week plus was found in one-third of the iopamidol and one-sixth of the iohexol patients. These two studies demonstrate that outpatient radiculography can be performed without an increased incidence of side-effects. Minor, but nevertheless significant, differences were demonstrated between the two contrast media that prompt the authors to express a preference for iohexol.

Imaging of epidural spread from paravertebral lymphoma

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Neurological manifestations from secondary lymphoma may result from haematogenous metastases to neural tissue, meninges and bone. Alternatively, epidural invasion may be seen in association with a paravertebral lymphomatous mass. Epidural spread of lymphoma from the paravertebral region may present with cord compression, a variety of more subtle neurological syndromes or it may be imaged whilst asymptomatic. We report a series of 12 patients in whom epidural spread from paravertebral lymphoma has been demonstrated by modalities including myelography, CT and magnetic resonance imaging. The clinical and radiological findings are reviewed. Our series show that invasion of the epidural space frequently occurs via the intervertebral foraminae without bone destruction. Normal spinal radiographs should not deter the radiologist from employing other imaging techniques in investigating neurological symptoms in patients with lymphoma.

Out-of-hours computed tomographic head scanning: an audit

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With the increased availability of computed tomographic scanning facilities in district general hospitals, demand for a service outside normal working hours is likely to develop. This centre, a district general hospital with sub-regional specialist units for neurology and neurosurgery, has provided such a service since 1976. A retrospective analysis of all cases scanned "out-of-hours" is presented. Where possible, the contribution of the service to patient management is assessed. Discussion focuses on the indications for out-of-hours scans.

Correlation of presence, site and type of skull fracture with intracranial damage

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In order to correlate skull fractures and intracranial damage, a series of 1383 head-injured patients admitted to a regional neurosurgical unit was studied. This study is unique in that all the skull radiographs and computed tomographic scans were all reviewed by one consultant neuroradiologist. The results were analysed by the other author. The fractures were subdivided according to type, side and bone principally involved, and intracranial damage was classified into contusion and extradural (ED), subdural (SD) and intracerebral (IC) haematoma. Damage was related to the side and type of fracture, if present, and the features of fractures unassociated with intracranial damage were also analysed. Results are displayed diagrammatically, and the major findings are as follows. Skull fracture was present in 850 (70% associated with damage) and there was no skull fracture in 533 (46% associated with damage). The type of fracture and percentage associated with intracranial damage were: linear (74%), linear + depressed (65%), depressed (52%). The site of fracture and associated damage were: (i) frontal fracture, total damage (80% anterior, 4% posterior, 16% both); (ii) occipital fracture, total damage (56% anterior, 12% posterior, 32% both); contusion (87% anterior, 6% posterior, 8% both); haematoma (40% anterior, 16% posterior, 45% both); and (iii) lateral fracture, total damage (62% ipsilateral, 25% contralateral, 13% both). Types of intracranial damage were: contusion 77% (ipsilateral 56%, contralateral 22%, bilateral 22%); ED 87% (ipsilateral 97%, contralateral 3%); SD 72% (ipsilateral 67%, contralateral 22%, bilateral 11%); and IC 66% (ipsilateral 54%, contralateral 32%, bilateral 14%).

Cerebral angiography performed with oral premedication alone: a trial of 40 patients

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Traditionally, cerebral angiography has been performed under general anaesthesia or with intravenous sedation. General anaesthesia, especially when administered in a radiology department, has a significant morbidity. Variation in the level of consciousness during intravenous sedation can result in patient movement, producing considerable image degradation during digital subtraction procedures. Low-osmolar, non-ionic contrast media have significantly reduced the discomfort of angiography. Decreasing sedation should improve patient co-operation and allow early recognition of neurological complications. To test this hypothesis we performed a series of 40 consecutive cerebral angiograms with a premedication of temazepam and infiltration of local anaesthetic alone. Digital subtraction angiography (DSA) with iohexol 140 (Omnipaque Nycomed) was used in 55 cases; occasionally the DSA images were complemented by conventional images. The diagnostic quality of the DSA images was assessed by two neuroradiologists, and patient movement measured by the displacement of a radio-opaque marker attached to the patient's head. Adequate diagnostic images were obtained in 39 patients. In four, considerable re-registration of images was necessary to obtain diagnostic studies; all of these patients were extremely drowsy. Patient reaction to the procedure was determined by means of a questionnaire. Twenty-eight of these were returned. Thirteen patients were satisfied with the level of sedation but only four found the procedure was worse than expected and overall most discomfort was caused through lying on the table. For comparison, a review of the angiographic practice of neurological units in the UK was undertaken. Our findings indicate that cerebral angiography, which is both diagnostic and acceptable to the patient, can be performed under oral premedication alone.

Percutaneous transluminal angioplasty of the internal carotid artery: protocol and initial experience

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Percutaneous transluminal angioplasty of the internal carotid artery (PTAICA) has been attempted in seven patients with symptomatic cerebral ischaemia, which was thought to be due to cerebral hypoperfusion. Each had a stenosis of one ICA accompanied by occlusion of the other. The procedure was technically successful in four patients and resulted in clinical improvement. In two patients it proved impossible to selectively cannulate the ICA. In one patient with stenosis due to fibromuscular dysplasia (FMD), the ICA stenosis could not be traversed by the guidewire. Two patients experienced transient neurological deficit following the procedure. Following a successful dilatation, one patient suffered weakness of the arm which resolved completely within 2 h. The patient with FMD became aphasic, which caused the procedure to be abandoned. Speech returned within 10 min. None of the patients suffered permanent sequelae. We believe that PTAICA is a valuable alternative to carotid endarterectomy in selected patients. The exact protocol is described in what, to the authors' knowledge, is the first account of this procedure in the United Kingdom.

Interventional neuroradiology: Swedish style

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I would like to describe my experience of interventional neuroradiology as practised in Sahlgrenska Hospital, Gothenburg, where I spent 2 months as a result of a Nycomed Scandinavian Scholarship awarded by the British Institute of Radiology. Twenty-nine interventional procedures were performed on 26 patients. Intracranial arterio-venous malformations (AVM) (13) were treated by selective catheterization of the arterial feeders using either a calibrated leak balloon or tracker (target therapeutic) catheter and embolizing with IBCA. Complete occlusion of the nidus was achieved in one case while partial obliteration was observed in the rest. In one case the microcatheter was unfortunately glued in the feeding artery but the patient's neurological status did not change. In three patients with dural fistulae, branches of the external carotid artery were selectively embolized using IBCA or PVA. All patients had symptomatic relief. Carotid cavernous fistulae (2), carotid–ophthalmic aneurysm (1) and pulmonary AVM (1) were successfully treated using transvascular detachable balloon occlusion. In one patient with spinal AVM, the first procedure had to be terminated owing to traumatic dissection of the feeding artery. Fortunately, this was not associated with neurological deterioration and a repeat procedure a month later demonstrated a complete recovery. The AVM was embolized using PVA. Cavernous haemangiomas (5) were treated by percutaneous installation of pure alcohol. Different interventional techniques are discussed.

Teach-in: Modern Intracavitary Brachytherapy

Chairman: Dr R. D. Hunter

Let's get the physics straight
J. M. Wilkinson
The radiobiological basis for low-dose-rate radiotherapy
G. G. Steel
Clinical aspects of modern techniques
R. D. Hunter

Let's get the physics straight!

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When the revised Manchester method for intracavitary brachytherapy was published some 36 years ago the authors described flexible rubber applicators into which were loaded radium tubes sheathed in platinum. The sources were specified in terms of their content, *i.e.* the number of milligrams of radium that each contained, and the treatments were prescribed by stating the required exposure at Point A in Manchester roentgens. The exposure rate at Point A, and hence the duration of the treatment, was determined from tabulated data of milligram hours per 1000 'R', and no correction for attenuation and scattering of the radiation in the tissues was attempted. Today, afterloading techniques tend to require rigid applicators and sources of different sizes and shapes. The radionuclides used are now most commonly ^{137}Cs, ^{192}Ir or ^{60}Co, and are specified in terms of their emission, and, if we follow the current national and international recommendations, this will be the air kerma rate at 1 m in units of μGy h^{-1}. Doses are prescribed in Gy, total reference air kerma has replaced milligram hours, and computers allow detailed and more sophisticated calculations. All these changes provide many possibilities for confusion and error. Some of the changes will inevitably introduce real, though hopefully minor, changes in physical distribution of dose within the pelvis and these need to be appreciated and understood. Others need be no more than changes in the terminology and need not affect the treatment in any way, provided that we successfully get the physics straight.

The radiobiological basis for low-dose-rate radiotherapy

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The principal reasons for choosing interstitial or intracavitary radiotherapy in preference to external-beam treatment relate to dose delivery and dose distribution rather than to radiobiology. But the question of whether low-dose-rate irradiation itself carries a therapeutic advantage is an interesting one. There is a considerable volume of literature on the radiobiology of human tumours and there is evidence that local tumour control by radiotherapy correlates with the initial slope of the oxic cell survival curve. The size of the dose-rate effect varies widely among human tumour cell lines, as also among normal tissues of the mouse. The availability of this information allows the effects of dose inhomogeneity in brachytherapy to be considered more realistically than in the past. The probability of eradicating all clonogenic cells within small regions of the tumour varies steeply with dose, and thus with position within the radiation field. The position of the cut-off in cure probability depends upon the steepness of the cell survival curve for the dose-rate that exists at that point (in the region of 1 cGy/min). The change of steepness within the radiation field by itself has little effect. In comparing the radiobiology of interstitial and external-beam radiotherapy it should be remembered that fractionation and low-dose-rate irradiation exploit the same recovery mechanisms. Dose sparing achieved by multiple fractions reduces that which comes from lowering the dose-rate. With conventional treatments the sparing achieved by fractionation is often at least as great as is achieved by interstitial therapy.

Clinical aspects of modern techniques

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The intracavitary systems that are the basis of modern practice evolved empirically over nearly five decades at the beginning of the 20th century. Practice led theory, particularly in the radiobiological and physical aspects of the treatments. These latter features almost caught up in the 1970s, but then the age of sophisticated computer-controlled afterloading equipment and individual patient three-dimensional dosimentry arrived. These most recent changes allow the radiotherapist to ask the manufacturer for a bewildering variety of applicators and to choose from an enormous range of dose-rates and dose distributions. The new radiotherapist can choose to be a conservative or a radical. Unfortunately, both choices have their problems. There is no reason why modern equipment cannot service classical style applicators and operate at true low dose-rates. Such an approach needs careful attention to the applicator design and to patient comfort during these long, isolated treatments. This approach is best seen in the modern Paris School. Other schools have gone for new applicators, increased dose-rates and fractionation. Which of the approaches is best and how should they best be measured? How safely can the classical empirical treatments be subjected to local changes? Does individual patient dosimetry matter and how should it be gathered?

Dose-fractionation Results

Chairmen: Drs S. J. Arnott and J. W. Hopewell

British Institute of Radiology studies of dose fractionation in radiotherapy for tumours of the laryngo-pharynx
G. Wiernik, M. Rezvani and members of BIR Fractionation Working Party
Radiobiological basis for future improvements in dose fractionation in radiotherapy
K.-R. Trott
Accelerated fractionation in invasive bladder cancer
K. R. Durrant, D. J. Cole and J. W. Hopewell
Continuous, hyperfractionated, accelerated radiotherapy and why
S. Dische and M. I. Saunders

British Institute of Radiology studies of dose fractionation in radiotherapy for tumours of the laryngo-pharynx

G. Wiernik, M. Rezvani and members of
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Two prospective, randomly allocated clinical trials have been conducted in 20 centres in the United Kingdom to assess tumour control and normal-tissue reactions, both early and late, in the irradiation of laryngo-pharyngeal cancer when comparing three fractions/week versus five fractions/week (734 patients) and short versus long overall treatment time (611 patients). Follow-up for 10 years or to earlier death has already been achieved for the majority of patients included in the trials. No statistically significant differences in survival, tumour-free or laryngectomy-free rates are apparent between the groups being compared. The possible implications of those differences that have been shown are discussed. Details are reported concerning the important factors that have contributed to the successful completion of both trials and the statistical methods employed that have allowed restriction of the length of the follow-up period in the second trial. The data from the trials have enabled us to assess the predictive value or otherwise of parts of the TNM classification of tumours and possible modifications in the system where it has failed to provide differentiation are proposed. Reference is made to the curative role of radiotherapy in relation to surgery in the treatment of laryngo-pharyngeal cancer as well as to the relative values of the individual components of a fractionation regime such as dose, fraction number and time factors. An assessment of the possible socio-economic advantages for both patients and the Health Service from the use of curtailed fractionation regimes in relation to the recently reported data on the current practice of radiotherapy in the United Kingdom is considered. The reliability of the limited new data as the basis for the general introduction of hypofractionation regimes is assessed in terms of field size, irradiated volume, anatomical site and the radiation response of individual normal tissues.

Radiobiological basis for future improvements in dose fractionation in radiotherapy

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Clinical observations in squamous cell carcinomas and experimental studies in various mouse tumours demonstrate that in some tumours accelerated proliferation of surviving tumour stem cells occurs during the course of fractionated radiotherapy, which may be a major cause of tumour radioresistance. Between 15 and 25% of total tumour dose given by conventional radiotherapy of head and neck cancers may be wasted on the tumour, as it is used up only for compensating accelerated clonogen repopulation. However, experimental data suggest that accelerated repopulation of tumour stem cells only starts after some delay and may vary considerably between different tumours of the same histology and growth rate. Moreover, accelerated repopulation also occurs in normal tissues, and in oral mucosa it may, at some time during treatment, be even more efficient in compensating radiation injury than in some tumours and may have a similar time course. Optimal fractionation schedules should follow the dynamic changes in the differential repopulation rates in the individual tumour and the critical normal tissue. However, much better understanding of the biological phenomena responsible for accelerated repopulation is needed before new fractionation schedules can be recommended, which requires a close link between clinical and experimental research.

Accelerated fractionation in invasive bladder cancer

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In conventional radiation therapy extending over 6 weeks, cell repopulation is a major factor affecting normal tissue response and tumour cell kill. For acutely-responding tissue such as skin, the iso-effective dose may be increased by 10–20% by extending the overall radiation period from 3 to 6 weeks. Proliferation of clonogenic tumour cells in this period implies that a proportion of the radiation dose merely counteracts this increase in the number of clonogens. This proportion of the total dose depends largely on the potential doubling time of the individual tumour. A reduction in the overall time period of radiation therapy while using conventional total and fraction doses may increase the effectiveness of therapy, although acute effects on normal tissue might be increased. Accelerated fractionation is most likely to be of value in tumours with short potential doubling times (T_{pot}). Investigations of cell kinetics suggest that high-grade transitional cell carcinoma of the bladder has a potential doubling time of 3 days. The short latency time for local recurrence for these tumours accords with this estimated T_{pot}. A pilot study of accelerated fractionation for high-grade bladder cancers has been undertaken by the BIR Accelerated Fractionation Group in preparation for a prospective randomized trial to compare accelerated and conventional fractionation for these tumours. End-points are local control and acute and late toxicity. Early data suggest a small increase in acute toxicity and that a minor reduction of dose per fraction may be necessary. Patients for this therapy should be of good performance status (WHO 1 or 2) and have no history of abdominal surgery. The BIR Group and the Urological Cancer Group have planned very similar protocols with two identical fractionation schedules so that data can be pooled to increase the statistical power of these studies.

Continuous, hyperfractionated, accelerated radiotherapy and why

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A scheme of continuous, hyperfractionated, accelerated radiotherapy (CHART) was devised at Mount Vernon Hospital, influenced by the biological data suggesting that many tumours had a capacity for rapid repopulation. The overall duration of radiotherapy was reduced to 12 days and by treating three times each day, including the weekend, a total dose of 54 Gy was given in 36 fractions. A reduction in the incidence of late radiation damage was predicted because of the low dose of 1.5 Gy per fraction, but acute reactions were likely to be more severe with the acceleration of treatment. A total of 179 patients have now been treated in this fashion since the scheme was introduced in January 1985. Locally advanced carcinoma of the bronchus and of the head and neck region have comprised the bulk of the cases included. With both tumours the regime has been well tolerated and there has been improvement in local tumour control and in survival when comparisons were made with previously treated comparable cases. The planning of randomized controlled trials on a national basis is now well advanced and should begin early in 1989. If these trials confirm the success of the pilot study then the ability of human tumours to rapidly repopulate during a course of radiotherapy or chemotherapy will have been confirmed. It is quite possible that human tumours not only show a reduction of cell loss to zero, but also show among the surviving clonogenic cells a rise in the growth fraction.

The Management of Change

Chairman: Dr A. E. Hugh

What changes?
A. E. Hugh
What doesn't change — the patient?
M. J. Harvey
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J. Fielding
Radiology and general practice: a questionnaire survey
R. F. Bury

What changes?

A. E. Hugh
X-ray Department, North Staffordshire Royal Infirmary, Stoke-on-Trent

Does everything change? Technology changes, medicine changes and people change. X-rays are now almost 100 years on and the imaging technique which Röntgen introduced is now spawning newer imaging techniques, some X-ray based, some non-X-ray, but based on the same technical innovations that have allowed dramatic developments in safe X-ray imaging. Imaging is not the only investigative modality that has changed. There have been similar continuing changes in the ability to investigate disease and the human body, as there have been in imaging. Electron microscopy, allowing observation of body changes almost on a molecular level, and endoscopy, allowing inspection of internal abnormalities previously inaccessible to the eye, are but two of them. Disease also changes; maybe not the basic pathological processes, but certainly there is an unfortunate adaptation of disease and disease patterns because of altered standards of living, and of life styles. The ability to treat disease also changes, and this in its turn introduces problems. In their habits, both physical and social, people change. They also change in their expectancy of health, of health care, and of the health carers. They change because of their natural aspirations and ambitions, and they also change because of pressures exerted upon them by commercial influences. They also change because the law of the land changes, as does its application. Some things don't change: people are still persons, individuals, entitled to respect, to freedom, and to be treated in such a way that their personal dignity is both respected and maintained, an increasing problem in an increasingly complex world. This session intends glancing at some of the changes which are of particular concern to radiologists and radiographers and to allow discussion of the factors which produce change in our life to see if the change we produce is for the better.

What doesn't change — the patient?

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A great deal is being written about the need to treat the patient as a person. Has this arisen because of a change in the patient or in the perception of their needs, or has nothing changed? This question is discussed with reference to developments outside and inside the Health Service and how these have affected patients. Despite changes which have undoubtedly occurred, the philosophy that the patient doesn't understand what is good for them or cannot assess the quality of the service prevails in many areas in the Health Service. Examples obtained from working as a radiographer and more recently as Patients Services Manager are given in order to explore what the patient expects from the service and what we are providing.

The mechanics of change: implications for clinicians

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The mechanics of change has implications for the clinical head of department as well as the more general health care system. Changes that are occurring and will have considerable impact on clinical activity include: (1) demographic changes and forecasts, (2) movements in national policies (both political and economic), (3) technological change, (4) social attitudes and expectations, (5) professional developments (views on roles of radiologists/colleagues/scientific staff/other groups), and (6) what is this specialty and its future? This paper examines possible ways of dealing with these issues in the work situation and requests ideas from the conference for real and positive action to bring about better outcomes for our clients — the patients.

Change is inevitable: how is it managed?

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This paper recognizes the need for change and identifies some problem areas within the Department of Radiology at North Manchester General Hospital, where changes could be effected with minimum disruption and maximum potential benefit. It describes the negotiating processes employed and the resulting guidelines agreed. The difficulties of implementation and monitoring new working practices are outlined against a continually changing background within the hospital service.

The changing role of the radiologist

Thomas Sherwood
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Addresses on "Whither radiology" tend to be costive. New radiological tasks may make better subjects for discussion. There are tensions between what is now expected of radiologists and what they can deliver, and between technicians and doctors; the spread and apparent ease of new tools also poses problems for artisans. Facing up squarely to the difficulties of a rewarding journey is a start.

The changing role of the radiographer

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A brief outline of this role is given in order to establish a base-line. External changes peripheral to imaging and radiotherapy will have an impact on this role. Increasing technology in health care and improvements in treatment are altering the imaging pathways used in diagnosis and the treatment regimes prescribed in radiotherapy. The expectations of the population increase in relation to health care and the demand for imaging and radiotherapy services continues to grow. Changes are also taking place within the profession. There is a greater awareness of the importance of the role of the radiographer. Many are becoming involved in research undertaken in their departments and are studying for degrees, both at first and second level. Unfortunately, manpower trends within the profession show that many radiographers do not remain in the NHS after the age of 30 years, and recruitment of new entrants has fallen dramatically. A strategy to encourage returners and mature entrants in order to meet the manpower need will require changes in working practices to provide these people with the motivation to remain within the service. These controversial issues relating to the changing role of the radiographer are discussed. For example, the role of the radiographer in image interpretation as distinct from diagnosis, in patient counselling, in quality control and in increasing technology, such as image manipulation and the conversion of images from analogue to digital mode, are discussed. The lines of demarcation between different professional roles have become blurred but trust and co-operation will provide a better environment in which people can work, and perhaps with intellectual stimulation and job satisfaction the radiographer will again see a long-term career within imaging and radiotherapy. A positive approach to these changes in role will lead ultimately to benefits in health care for the patient.

A & E: a problem clinical area

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One person out of five attends an Accident & Emergency department annually. Last year there were just over 11 million A & E attendances nationally. The A & E department at Russells Hall Hospital, Dudley had about 80 000 new attendances and a further 55 000 follow-ups last year. Sixty-five per cent of the work done by the Radiology department at Russells Hall Hospital originated from the A & E department. The original aim of our colleagues in radiology was to provide hot reporting of A & E work between the locums of 9.00 am and 5.00 pm. This still remains a dream. There is a system of fractional reporting from new requests and virtually none from the follow-up work from fracture clinics. However, there is an excellent "help" facility both for the juniors and the consultants. Radiographers are technicians of a special kind and it is best that they are responsible to radiologists who can appreciate their work and practices better than A & E consultants. However, a close working relationship with A & E consultants cannot be overstressed. There is no place in the A & E environment for non-medics to request X-ray examinations.

A problem area: the Accident & Emergency Department

J. A. Fielding
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Accident and Emergency (A & E) reporting makes a significant contribution to the workload of many radiologists. There is frequently poor selection of patients for referral, too many unnecessary requests, and the frustration of reporting a problem dealt with long ago. Without special training, there is a significant degree of misinterpretation of radiographs by Casualty Officers, some of these errors being clinically important. At present most A & E radiographs are seen later by a radiologist, but much more selective reporting can be done if interpretative skills of Casualty Officers are improved, and particularly if there is an A & E Consultant in post. Radiological ability of A & E doctors is improved by better instruction, both before and after taking up a post, with a teaching programme including radiology seminars and lectures from radiologists. Junior doctors are encouraged to seek advice in difficult cases, from the A & E Consultant or a radiologist. Improved radiological ability includes recognition of the normal and quick diagnosis of the abnormal. The patient is treated more efficiently and there is less dependence on the radiologist for routine reports. Most radiology departments have experienced an annual increase in referrals from the A & E Department, frequently a proportionally greater rise than numbers of patients seen in the A & E Department. Reasons for this include greater expectations of technology from both patients and doctors, and the increased fear of litigation. Because of difficulties standardizing criteria for X-ray requests, guidelines are not easy to draw up. Nevertheless, there are certain circumstances where radiographic findings do not influence treatment, *e.g.* certain head injuries, nasal injuries, soft-tissue ankle injuries, rib views and erect abdominal radiographs in the acute abdomen. Studies show that the introduction of guidelines results in a drop in the referral rate for X-ray examinations. Experienced radiographers are able to identify abnormalities on a radiograph, which junior Casualty Officers may not see. The interest and work satisfaction of radiographers may be heightened by having a system whereby they may stick a spot on the radiograph if they think there is an abnormality present. This is brought to the attention of the Casualty Officer. The aim of change in radiological practice in the A & E Department must be directed to giving a better service to the patient, with rapid diagnosis and by eliminating unnecessary investigations which result in patient irradiation, extra expense, and time wasting.

Radiology and general practice: a questionnaire survey

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A questionnaire survey of 100 general practitioners (GPs) using two radiology departments was carried out in an attempt to assess how well informed they were concerning current radiological practice. A second questionnaire was given to 80 consecutive outpatients attending for barium studies or intravenous urograms (IVUs) to see how much information they had been given by their GP about the proposed investigation. Of the 72 GPs who replied, 61 (85%) said that they needed to have some knowledge of the newer imaging techniques, and 58 (81%) felt that they were lacking in this respect. Of more concern was the fact that 19 (26%) claimed that their knowledge of basic investigations such as IVUs and barium studies was insufficient to prepare patients for the examination. Answers to other questions concerning radiation hazards and communication of results to patients are presented. The results of the patients' questionnaire confirmed that although 77 (96%) would have welcomed some information about the proposed examination, only 35 (44%) had actually been given any such preparation by their GP. While this may be partly due to a failure by the patients to absorb information during the consultation, it must also be a consequence of the GPs' self-confessed ignorance of radiological practice, possibly coupled with a tendency to underestimate the anxiety engendered by radiological referral. It is suggested that this unsatisfactory state of affairs is partly the fault of radiologists, and methods of enabling GPs to make better use of imaging facilities are discussed.

Musculoskeletal Imaging and MRI: proffered papers and posters

Chairman: Prof. I. Isherwood

^{31}P magnetic resonance spectroscopy of the human liver: changes in T_1 in disease
I. J. Cox, D. G. Gadian, J. Sargentoni, I. R. Young, D. J. Bryant, G. M. Bydder and G. A. Coutts
Magnetic resonance imaging of the marrow in patients with neuroblastoma: a comparison between magnetic resonance imaging, MIBG marrow imaging and marrow aspirates
J. F. C. Olliff, J. S. E. Moyes, C. R. Pinkerton, M. P. Williams, G. R. Cherryman, S. T. Meller and J. E. Husband
Magnetic resonance imaging of the aorta: comparison of field even-echo rephasing and spin–echo techniques
L. Mitchell, J. P. R. Jenkins and I. Isherwood
Magnetic resonance angiography, quantitative blood flow measurement and chemical-shift imaging of atheroma in peripheral vascular disease
C. Sampson, R. H. Mohiaddin, S. R. Underwood, D. N. Firmin, R. S. O. Rees and D. B. Longmore
Magnetic resonance imaging of para-aortic masses from testicular teratoma
P. Goddard, S. Goodman, A. Case and A. Troughton
Magnetic resonance imaging of undescended testes
P. Goddard, A. Longstaff, J. Waring and A. Troughton
The clinical potential of echo planar imaging of the fetus
B. S. Worthington, I. R. Johnson, M. K. Stehling, R. Ordidge, R. Coxon, B. Chapman, D. Guilfoyle, A. M. Houseman, A. Blamire, P. Gibbs, E. M. Symonds, R. E. Coupland and P. Mansfield
In vivo localized ^{31}P spectroscopy of human breast carcinoma
J. Glaholm, J. C. Sharp, D. Collins, N. P. Rowell, M. O. Leach, K. Farnsworth, V. R. McCready and A. J. Hind
Oral magnetic particles: a new oral contrast agent for abdominal magnetic resonance imaging
D. Kean, J. J. K. Best, L. W. Turnbull, H. McRitchie, D. C. Carter and M. Wright
Bone mass in primary hyperparathyroidism
J. E. Adams, R. W. Whitehouse, P. H. Adams and M. Davies
Quantitative computed tomography bone mass measurement in patients receiving treatment for endometriosis
R. Whitehouse, J. E. Adams, K. Bancroft, C. A. Vaughan-Williams and M. Elstein
Beware of the child with torticollis and a fractured clavicle
J. Stabler, N. J. Goddard and J. S. Albert
A magnetic resonance imaging study of the morphological changes in the intervertebral disc following treatment of a protrusion by surgical discectomy, the percutaneous nucleotome and chemonucleolysis
B. S. Worthington, P. Wilde, A. North, R. C. Mulholland and R. W. Kerslake
Magnetic resonance imaging of isolated lumbar disc syndromes: a multi-sequence approach
W. R. Saywell and R. E. Steiner
Sacroiliitis associated with IgA nephropathy
F. J. Gilbert, A. M. MacLeod, C. Eastmond, N. Edward and G. R. D. Catto
A finite element model of the hip: biomechanical patterns and their relation to the radiological appearances of early Perthes' disease
A. D. C. Hogg, B. S. Choo, R. G. Burwell, A. Moulton and B. S. Worthington
The radiological investigation of solid calf masses
P. C. Rowlands, I. W. Brown and M. A. O. Al-Kutoubi
The radiology of alveolar soft-part sarcoma
J. E. Kabala, D. Dunlop, A. Chalmers, J. R. Pilling and C. Marsh
Radiographic abnormalities and synovial fluid analysis in symptomatic and asymptomatic knees
S. J. Austin, A. R. M. Wilson, M. Pattrick, E. Hamilton and M. Doherty

^{31}P magnetic resonance spectroscopy of the human liver: changes in T_1 in disease

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Phosphorus-31 magnetic resonance (^{31}P MRS) spectra from regions of pathology within the human liver often show differences compared with normal. The interpretation of changes in PME and PDE peaks is unclear since the chemical compositions of the peaks is ambiguous from the *in vivo* spectrum. An additional variable in disease is the spin-lattice relaxation time (T_1). In general, it is difficult to obtain a measure of T_1 from a localized region because of the low sensitivity of the technique and consequent time constraints of a clinical examination. When only crude localization is required, for example in the study of diffuse liver disease, it is feasible to assess the relaxation parameters. Spectra are obtained at a number of repetition times (TR = 500–5000 ms) from parasagittal planes using one-dimensional phase encoding technique. In certain case studies (viral hepatitis, diffuse malignancy, obstructive jaundice) changes in the T_1 of PME and PDE are observed. The T_1 of PME is increased, and the T of PDE decreased. A change in T_1 indicates either a change in the environment of a normally occurring metabolite or the presence of a different compound. If valid quantification of metabolites is to be achieved, this variation of time constants must be considered. Further optimal sensitivity and contrast in disease are not necessarily achieved using acquisition conditions that are most appropriate for control subjects.

Magnetic resonance imaging of the marrow in patients with neuroblastoma: a comparison between magnetic resonance imaging, MIBG marrow imaging and marrow aspirates

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The presence of fat within the normal adult marrow causes T_1-weighted marrow images to display a high signal. The replacement of normal fat by cellular material leads to a reduction in marrow signal. Thus, in adults, magnetic resonance imaging (MRI) is a sensitive method for the detection of marrow disease. In children, bone marrow has a higher cellular component due to normal haemopoietic tissue and the distinction between normal and abnormal marrow is more difficult. In this paper we discuss the difficulty of interpreting MRI of paediatric bone marrow and present the results of 10 patients with neuroblastoma that we have studied. Marrow imaging with MRI in patients with neuroblastoma was compared with ^{123}I-MIBG marrow imaging and marrow aspirates. Magnetic resonance imaging is as sensitive as MIBG marrow imaging in the detection of marrow disease in these patients. In some patients following treatment, MRI demonstrates abnormal marrow signal when MIBG imaging is negative. The various causes of this discrepancy are discussed.

Magnetic resonance imaging of the aorta: comparison of field even-echo rephasing and spin–echo techniques

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The aim of this study was to assess the clinical utility of the field even-echo rephasing (FEER) sequence, compared with the spin–echo (SE) technique, in the study of aortic disease. Flowing blood in the aorta on SE imaging provides negative contrast whereas with the FEER sequence the signal is recovered, giving a positive contrast. Areas of disturbed flow cause signal loss using this sequence. In addition, the FEER sequence can provide quantification of blood flow velocity and can be used to acquire multiple images at one anatomical level during a cardiac cycle (cine) or single images at several levels (multislice). Aortic imaging was performed in 35 patients using cardiac-gated multislice spin–echo and multislice and cine FEER sequences on a 0.25 T Picker International superconducting magnet system. Patient diagnoses included normals, aortic aneurysms, dissections, coarctations and aortitis. The cine FEER sequence provided improved contrast compared with SE and multislice FEER and proved especially valuable when intraluminal detail was required, as in the identification of a dissection flap. A particular disadvantage of the cine FEER sequence was that data were provided at only one anatomical level and its use over multiple levels was precluded because of time constraints. Multislice FEER provided poorer contrast than multislice SE. Signal loss due to disturbed flow was a sensitive but non-specific indicator of abnormality. Velocity measurements could not be made in areas of signal loss (*e.g.* coarctation). In MRI of aortic lesions the SE and cine FEER sequences were complementary techniques, providing useful information in differential diagnosis.

Magnetic resonance angiography, quantitative blood flow measurement and chemical-shift imaging of atheroma in peripheral vascular disease

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Eleven patients with peripheral vascular disease diagnosed by radiographic angiography were studied using a 0.5 T magnetic resonance scanner. Spin–echo images in transverse and obliqued coronal planes showed the anatomy of the abdominal aorta and iliac arteries. Atheromatous regions in the aorta were scanned by chemical-shift imaging using the slice selection reversal technique, which enables lipid content to be assessed and the area of the plaque to be measured. Velocity mapping by field even-echo rephasing (FEER) enabled quantitative measurements of blood flow in the aorta and iliac arteries to be made. Five normal subjects were studied for comparison. The magnetic resonance anatomical images were comparable to the radiographic images. In eight cases of atheroma in the aorta, chemical-shift imaging showed it to be fibrous in five cases and to have lipid areas in three. In nine cadaveric aortas studied, histological correlation was good. In six patients who had decreased flow in one iliac artery, a stenosis was seen in both the magnetic resonance and radiographic images. In one case studied both pre- and post-iliac angioplasty, the blood flow post-angioplasty increased. Magnetic resonance can be used as a non-invasive method of assessing peripheral vascular disease and its progression and response to treatment. In the surgical management of patients, measurement of blood flow in the aorta and iliac arteries may be helpful in deciding whether surgery of more distal lesions would be successful.

Magnetic resonance imaging of para-aortic masses from testicular teratoma

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Following treatment for testicular teratoma, para-aortic lymph node masses persist in a small percentage of patients. The masses are usually demonstrated by computed tomography (CT) but this technique only gives accurate information about the size and not the nature of the mass. A mass identified in this way may represent active tumour, benign cystic transformation or fibrosis. Aberrant vessels (*e.g.* testicular vein, varices or collaterals) or bowel may be incorrectly identified as a mass. Eight patients with persistent masses were scanned using a Picker 0.5 T Vista magnetic resonance scanner. The sequences used were: (a) T_1-weighted spin–echo, (b) T_2-weighted spin–echo (with motion artefact suppression technique, MAST) and (c) STIR (short tau inversion–recovery). The patients were scanned in all three planes. In six cases persistent masses were identified and magnetic resonance imaging revealed information about the cystic or solid nature of each mass. In one case, large aberrant collateral vessels were shown over a solid mass. Metastatic disease in the spine was also demonstrated. In one case, no mass was identified but subsequent CT scans showed the originally reported mass to be an unopacified loop of bowel. Magnetic resonance imaging may prove of value in the assessment of persistent para-aortic masses in patients with testicular teratoma.

Acknowledgments to: Cancer in Focus.

Magnetic resonance imaging of undescended testes

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Demonstration of undescended testes is important in childhood in order that the testis may be correctly relocated. In adults the undescended testis is normally removed because of the high risk of malignancy. Ultrasound will correctly site some superficial impalpable testes but not testes that are intra-abdominal. Seven patients with nine undescended testes (two bilateral) were scanned using a Picker 0.5 T Vista magnetic resonance scanner. In five patients (seven testes) the scans demonstrated the testes. In two cases the testes were not identified. The testes were seeen as a high-signal ovoid on T_2-weighted and proton density scans with a surrounding low-signal line. On T_1-weighted scans the testes had the same signal intensity as muscle. Magnetic resonance imaging is non-invasive and does not use ionizing radiation, particularly important if the testes are to be preserved. If there are bilateral undescended testes, they can be preserved for function but safely monitored by repeated magnetic resonance scans.

Acknowledgments to: Cancer in Focus.

The clinical potential of echo planar imaging of the fetus

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Reduced imaging time which permits better patient tolerance and the elimination of obtrusive artefacts arising from fetal movements are important benefits of ultra-high-speed imaging during pregnancy. Twelve women in the third trimester of pregnancy were examined by echo planar imaging (EPI) after clinical and ultrasound examinations which indicated an abnormal gestation. Imaging was carried out at 0.52 T employing a low-inductance, actively screened coil system. Using an adaptation of EPI, employing the modulus blipped echo-planar single-pulse technique (MBEST), high-quality contiguous transverse axial slices of 10 mm thickness were obtained in 128 ms with a true matrix display of 128 × 128 without the need for signal averaging. The high intrinsic T_2 weighting of MBEST images allows excellent depiction of soft tissues. The placenta, umbilical cord and surface features of the fetus are well shown, contrasted against the high signal of the amniotic fluid. Assessment of the thickness of subcutaneous fat may assist in the assessment of the growth retarded fetus. In the thorax the lungs with their high fluid content are contrasted against the heart, where the changing blood flow pattern could be observed on a sequential image of a four-chamber view. All the major abdominal organs were identified with structural detail apparent in the liver and kidneys. From a stack of contiguous slices it is possible to calculate the volume of the major organs. In the limbs the diaphysis and the epiphyses of long bones were noted in addition to soft-tissue detail. In two fetuses with gastroschisis there was clear depiction of the abdominal wall and bowel loops within the amniotic fluid. In a fetus with a diaphragmatic hernia the abnormally situated bowel within the thoracic cavity was well shown together with accompanying displacement of mediastinal structures and compression of the lungs. These studies illustrate the potential of EPI to assess fetal abnormalities.

In vivo localized ^{31}P spectroscopy of human breast carcinoma

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In vivo ^{31}P magnetic resonance spectroscopy provides an opportunity for non-invasive assessment of the response of tumour metabolism to therapeutic intervention. Early prediction of treatment response and disease relapse are of considerable clinical importance. The anatomical proximity of the breast to underlying skeletal muscle necessitated an accurate method of volume localization in order to prevent contamination by the strong signal from muscle. We have demonstrated the efficacy of a modified ISIS localization sequence and the inadequacy of surface coil "localization". Eight patients with locally advanced breast carcinoma have been assessed during treatment. In contrast to unlocalized spectra, ISIS localised spectra demonstrated low or absent P_{cr} in all of the tumours examined. Five were treated with combination chemotherapy, two with tamoxifen and one with external-beam irradiation. Three patients responding to chemotherapy demonstrated spectral changes, predominantly reduction of the PME and PDE peaks, bioenergetic changes (ATP, P_i, P_{cr}) were less consistent. In two patients these changes preceeded the clinical response. No spectral changes were observed in the remaining two non-responding patients. One of the tamoxifen-treated patients showed neither spectral nor clinical response to therapy. The second demonstrated a generalized increase of the NMR signal 2 weeks after commencing tamoxifen, with concomitant increase in tumour blood flow as measured by ^{99}Tc^{m}-labelled HMPAO. However, there was no change in tumour volume. The observed spectral changes may therefore represent a subclinical tumour flare. No spectral changes were observed during treatment in the patient undergoing radical external-beam breast irradiation, despite a reduction of tumour volume. Three months after completing radiotherapy there was loss of signal intensity and in particular reduction of the PME peak. In conclusion, we have demonstrated that ^{31}P NMR spectroscopy provides a non-invasive method for assessing therapeutic response in the treatment of breast cancer. The technique appears to be a sensitive indicator of response and we have observed spectral changes that preceeded clinically measurable changes in tumour volume.

Oral magnetic particles: a new oral contrast agent for abdominal magnetic resonance imaging

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A new oral contrast agent for use in abdominal MRI has been formulated by Nycomed AS and clinical trials with this product are beginning. The magnetic particles are composed of magnetic iron oxide incorporated in a monodisperse polymer particle. The effect of this contrast medium is to shorten the T_2 relaxation time thereby producing a signal void. *In vitro* experiments showed that significant image artefacts were produced and that these artefacts increased with concentration of oral magnetic particles (OMP), pulse sequence used and orientation relative to B_0. The optimum dosage of OMP was calculated from this work to be 0.1 g/l. More artefacts were produced using a field-echo sequence and also when the orientation of the sample was not in the same direction as B_0. Results from volunteer experiments have shown that the optimum dose of this agent for labelling the proximal small bowel was approximately 600 ml of OMP (0.1 g/l) 10 min before scanning commenced. An interleaved SR/IR T_1-weighted sequence (TR 1 s, TI 200 ms) was used to image the abdomen using transverse and coronal planes. The transverse sections were repeated to assess the passage of OMP into the distal small bowel. The problems of artefact production which had been anticipated from *in vitro* experiments were not a significant problem in *in vivo* imaging and the initial results from volunteers and patients show great promise for the use of OMP in abdominal imaging, particularly in the upper abdomen.

Bone mass in primary hyperparathyroidism

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Parathyroid hormone is a potent stimulator of bone resorption but only a small proportion of patients with primary hyperparathyroidism present with classical osteitis fibrosa cystica. The remainder without clinical bone disease are thought to be at increased risk of vertebral and peripheral fracture. In recent years more and more patients have come to diagnosis by chance and are then found to have mild, and commonly asymptomatic, disease. The management of these patients is the subject of debate, but many are treated conservatively, and then without serious deterioration in renal function. The effects of long-sustained, mild hyperparathyroidism on the skeleton is uncertain and may predispose to osteoporosis. We have assessed bone mineral in the peripheral and axial skeleton in 135 patients with primary hyperparathyroidism, many with mild disease and treated conservatively. Vertebral trabecular bone mineral was measured by quantitative CT and peripheral bone mineral was measured in the distal forearm by single photon absorptiometry. The majority of patients had normal vertebral bone mineral when compared with published normal data, although longitudinal measurements confirmed accelerated vertebral bone loss in some patients. Bone mineral was significantly reduced in the radius, and cortical bone mineral was more severely affected than trabecular bone. Longitudinal studies in patients treated surgically showed increase in vertebral bone mineral.

Quantitative computed tomography bone mass measurement in patients receiving treatment for endometriosis

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Danazol, an anabolic steroid which depresses oestrogen production, is used in the treatment of endometriosis. However, the drug may cause unpleasant side-effects (weight gain, hirsutism) in some patients. Nafarelin, a synthetic gonadotrophin-releasing hormone agonist, has therefore been suggested as an alternative treatment. Nafarelin induces reversible pituitary suppression with consequent decrease in ovarian steroid production, and this decrease is more profound than with danazol. A study was performed to examine the relative efficacy of nafarelin and danazol in the treatment of endometriosis and to determine using quantitative computed tomography (QCT) whether changes in trabecular bone mass were induced by treatment. Twenty-four women (aged 24–44 years, mean 32 years) with proven endometriosis, were randomized in a double-blind study to receive either nafarelin (15 patients) or danazol (nine patients) for 6 months. Using a GE 9800 scanner, three QCT (single and dual energy) vertebral trabecular bone mineral measurements were made in each patient at the start and end of treatment, and 6 months after therapy had stopped. Nafarelin caused a significant, but reversible reduction in bone mineral of −6% ($p < 0.001$). Conversely, danazol caused a small, but significant increase in bone mineral content (+1.4%, $p = 0.02$). Under the conditions of the study, these changes in bone mineral can be attributed mainly to alterations in bone turnover.

Beware of the child with torticollis and a fractured clavicle

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Five children are described presenting with a combination of fracture of the clavicle and atlanto-axial rotatory fixation (AARF). In the first three cases, diagnosis of AARF was delayed because the distortion of the cervical spine on standard views was assumed to be due to torticollis resulting from sterno-mastoid spasm. The delay in treatment results in some degree of permanent deformity. The experience of these three cases enabled us to make an early diagnosis in the last two cases and early treatment resulted in a rapid complete cure. Diagnosis of AARF depends on fluoroscoping the patient so as to obtain an accurate AP view of the axis. The relationship of the atlas to the axis is then analysed. Computed tomography is an ideal method of demonstrating the atlanto-axial joint and is mandatory if spot radiographs leave any doubt as to the diagnosis. The importance of early diagnosis is stressed. This depends on the radiologist being aware of the condition, especially in a child with a fractured clavicle, and ensuring that the appropriate views are taken.

A magnetic resonance imaging study of the morphological changes in the intervertebral disc following treatment of a protrusion by surgical discectomy, the percutaneous nucleotome and chemonucleolysis

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A magnetic resonance imaging study was carried out in three groups of 20 consecutive patients who were treated for disc protrusion by surgical discectomy, the percutaneous nucleotome and chymopapain chemonucleolysis, respectively.

Scanning was carried out prior to treatment and at intervals afterwards up to 3 months in the sagittal and transverse axial plane employing a T_1-weighted spin–echo sequence and the STIR sequence. The height of the treated disc was measured and compared with that of a normal disc as a control. The nuclear signal was graded and compared with the original level. The degree of bulging or protrusion of annular fibres was compared with the appearances prior to treatment. Compared with the control disc, that at the level of protrusion was an average 2 mm less in height and had a reduced nuclear signal. Eighty-five per cent of the patients had at least one other abnormal disc. After surgical discectomy there was a significant reduction in disc height at 4–6 weeks with a smaller further decrease at 3 months. There was also a reduction in the signal from the nucleus pulposus which progressed to complete loss in seven patients. Changes after percutaneous nucleotomy both in disc height and nuclear signal were less. After chymopapain chemonucleolysis there was gradual loss of remaining nuclear signal with complete loss by 6 weeks in most patients and this was accompanied by disc space narrowing. The appearances of the protrusion did not always change after treatment and never returned to that of a normal level. Residual bulging of the annulus was frequently present in the face of complete symptomatic relief.

Magnetic resonance imaging of isolated lumbar disc syndromes: a multi-sequence approach

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Lumbar disc disease is a significant cause of morbidity in all age groups. There is a spectrum of pathology ranging from widespread degenerative change through disc prolapses to single level disc resorption or disruption without prolapse. This paper examines the two syndromes of internal disc disruption (IDD) and isolated disc resorption (IDR), often unrecognized but eminently treatable causes of back pain in young patients. In a prospective study, patients referred during a 1-year period were examined on a 0.15 T MRI system using five different pulse sequences: $SE_{544/44}$ (high-resolution T_1-dependent image), $SE_{1500/80}$ (T_2 dependent), $SE_{1500/100/44}$ (short TI Inversion Recovery sequence for fat suppression), $PS_{500/33}$ (T_1 dependent) and $PS_{500/22}$ (T_1 dependent with chemical shift suppression of red marrow). In patients with one- or two-level disease and no prolapse, the features on MRI were assessed and related to radiological and clinical findings. There were 19 patients with single-level disease, with an average age of 35 years. Nucleus pulposus relaxation times (T_1 and T_2) were prolonged in 95% of patients. Disc narrowing was seen in 31% of patients aged less than 40 years and 86% of those over 40 years, and end plate veins were seen in 75% and 43%, respectively. End plate abnormalities were seen in 58%. Similar findings were made in the 18 patients with two-level disease, except that the age-related difference in disc narrowing was not observed. There was little difference between the syndromes of IDD and IDR in either group. The clinical significance of these and other findings are discussed, and it is concluded that MRI has an important role in the identification of these syndromes. Differentiation between the two syndromes is often easily made on clinical grounds; where difficulty exists, MRI permits specific targeting of further investigation such as discography.

Sacroiliitis associated with IgA nephropathy

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Sacroiliitis is found in a variety of conditions, notably the seronegative spondyloarthropathies. An association between these, in particular ankylosing spondylitis and IgA nephropathy, and immune-complex-mediated glomerulonephritis has been suggested in several reports. The nephrology service for Grampian Region (population 0.5 million) is confined to one centre where all renal biopsies are performed. The radiographs of all patients with biopsy-proven IgA nephropathy were reviewed to detect cases with sacroiliitis. Seventy-four patients diagnosed between 1977 and 1986 were studied. Radiographs were available for 66 of the 74 patients and in 58 the sacroiliac joints were sufficiently mature for sacroiliitis to be assessed; this was made from the IVU radiographs by two radiologists at a combined reading. Radiographs were deemed positive if there was unequivocal abnormality, that is Grade 3 or 4 in the Bennet & Woods' classification. This classification has been applied in the past, in population studies using AP radiographs to establish the prevalence of sacroiliitis. This gave a conservative estimate of the prevalence of sacroiliitis in IgA nephropathy. In our study, four males had unequivocal evidence of sacroiliitis (no female patients were affected) giving a prevalence of 7% overall; when males only were considered it was 8%. The expected prevalence of sacroiliitis in the United Kingdom is approximately 1%. This is the first study of the sacroiliac joints of a large group of patients with IgA nephropathy and our results show a much higher prevalence than expected. The radiological features are discussed in full together with the criteria used in different population studies, and various pitfalls in the interpretations of sacroiliac joints are mentioned, including the relevance of the patient's age. The clinical and immunological implications are discussed.

A finite element model of the hip: biomechanical patterns and their relation to the radiological appearances of early Perthes' disease

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The finite element method is a computer-based technique which provides the opportunity to determine stress (in terms of magnitude, direction and distribution) as well as deformation and dynamic behaviour of continuous structures. A two-dimensional model of the normal hip of a 4-year-old child has been created that allows for movement at the joint line. When the normal child's hip is loaded to simulate normal heel-strike, elastic deformations occur and the compressive stress is greatest supero-laterally and infero-medially in the cancellous bone and cartilage of the femoral head. These areas correspond to the sites of (a) flattening of the head and presumed stress fracture and (b) the increased tear-drop distance (attributable to cartilage thickening). Cartilage softening (by lowering its modulus of elasticity) and thickening each increase compressive stress supero-laterally and infero-medially in both cancellous bone and cartilage. Loading of the deformed femoral head exaggerates both the distribution of stress and the deformity.

Tensile stresses are found across the neck; these may contribute to the metaphyseal broadening and to the growth-plate irregularity of Perthes' disease. The distribution of these tensile stresses also coincides with the position of discrete radiolucencies found in the lateral epiphysis (Freund) and at three sites across the metaphysis (laterally, Gage; centrally, Waldenström; medially, Gill).

The radiological investigation of solid calf masses

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A number of patients presenting with solid calf masses are presented. These include patients eventually discovered to have solid tumours, both benign and malignant, and cystic masses. We present the results of the various methods of imaging used for their investigation and discuss the relative values of the various techniques. The literature relating to the subject is reviewed and our conclusions regarding the investigation of the calf and popliteal fossa are presented.

The radiology of alveolar soft-part sarcoma

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Alveolar soft-part sarcoma is a rare tumour accounting for only 1% of soft-tissue sarcomas. The radiological features of four cases recently encountered by the authors are described. The patients had a mean age of 20 years on presentation (range 4 to 35 years). The primary tumour in two patients (both female) was central (related to scapula and iliac wing) causing bone invasion and destruction. Both these patients had sizeable, well defined pulmonary metastases at presentation and in one patient these were responsible for her presenting complaint (haemoptysis). This patient is the only one to date to have manifested metastasis to the brain. In the remaining two patients, both male, the primary lesion was peripheral (foot and forearm) and showed pressure effects on the adjacent bones but no invasion or destruction initially (this was seen with recurrent calf tumour 3 years later in one patient). Neither of these patients showed distant metastases on 4-year follow-up.

Radiographic abnormalities and synovial fluid analysis in symptomatic and asymptomatic knees

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It has been suggested that certain radiographic features in the knee (in particular, large cysts, florid osteophytosis, and predominant patellofemoral disease) are associated with the presence of calcium pyrophosphate dihydrate (CPPD) crystals in synovial fluid. In contrast to this "hypertrophic" pattern of disease, the presence of hydroxyapatite crystals has been said to be associated with a more "atrophic" type of arthropathy. We studied the radiographs and synovial fluid of 300 individual knees, and in contrast to previous work, the study population included both symptomatic and asymptomatic joints. Weight-bearing AP and lateral radiographs were scored for features associated with osteoarthritis using a modification of the scheme of Thomas et al (1975). Synovial fluid was analysed using polarized light microscopy and alizarin red staining. The results are presented, and the relationship between radiological patterns of joint abnormality and synovial fluid crystal deposition is discussed.

Reference

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Dosimetry and Risk Estimates in Systemic Therapy

Chairman: Dr V. R. McCready

The treatment of malignant disease by systemic radiotherapy
D. Tait and C. L. Harmer
Techniques for dose estimation in systemic radionuclide therapy
M. Flower
Risk and benefit in systemic radionuclide therapy
J. Malone and P. J. Gilligan

The treatment of malignant disease by systemic radiotherapy

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Systemic radiotherapy, in the form of ^{131}I, has been used in the management of carcinoma of the thyroid since the 1940s. The availability of this long clinical experience has clarified the value of this form of management. For example, the Royal Marsden data shows that ^{131}I can achieve cure in patients whose metastatic disease is confined to the lung, and is particularly effective in young patients and/or those with well differentiated histology. An assessment of side-effects has also been made, with particular attention being directed towards the carcinogenic hazard. In the series from University College Hospital, London there was a small, significant excess of deaths from cancer of the bladder and from leukaemia with risk/rates of 0.4 and 4.9 deaths per 10^4 patient-year-Gy, respectively. Recently, considerable attention has been given to the use of radiolabelled monoclonal antibodies in an attempt to broaden the scope of this form of treatment. However, to date, this has not proved particularly successful, mainly because of poor antibody specificity and consequent low uptake of radionuclide. An alternative approach is to label a metabolic substrate with the aim of localizing radiation within a particular cell type. Metaiodobenzylguanidine (MIBG) is an analogue of guanidine, which is sufficiently similar structurally to norepinephrine to be taken up by adrenergic cells. When iodinated with radioiodine isotopes, this compound provides the potential to target radiation damage to tumours of neuroendocrine origins. Clinical development of this form of treatment has so far mainly been in children with neuroblastoma, but uptake and responses have been documented in phaeochromocytomas, carcinoid tumours, medullary carcinoma of thyroid and chemodectoma. There are a number of possible approaches for improving MIBG therapy, such as use of calcium blocking agents to increase MIBG uptake, and use of alternative radionuclides.

Techniques for dose estimation in systemic radionuclide therapy

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Estimates of radiation absorbed dose to tumour and to normal tissues are essential to optimize treatment regimes for systemic radionuclide therapy. However, accurate *in vivo* dosimetry is extremely difficult to achieve and, until recently, standard levels of radioactivity have been administered and few dosimetry calculations have been performed routinely. In the ideal situation where a radionuclide is selectively and uniformly taken up by a target organ, the absorbed dose to the target is proportional to the organ uptake (U) and the effective half-life (T_e), and inversely proportional to the target mass (m), the proportionality constant depending on the radionuclide used. Radioiodine 131, the most commonly used radionuclide for systemic therapy, is not the best radionuclide for the treatment of micrometastases but has the advantage of being both a β and γ emitter so that macrodosimetry is possible via *in vivo* imaging. U and T_e can be assessed using the well established techniques of quantitative radionuclide scanning. m is often more difficult to assess but is usually obtained from volume estimates made using a variety of imaging modalities: ultrasound, X-ray CT and NMR offer excellent spatial resolution, but the anatomical volume obtained from these devices may not truly reflect the functional volume of the tissues concentrating radioiodine. Alternatively, radionuclide imaging provides a means of assessing the functional volume but with poorer spatial resolution (especially for the high energy photons of ^{131}I where a gamma camera typically offers 20 mm resolution at 10 cm depth for planar imaging and 30 mm for emission CT (SPECT). The best spatial resolution (typically 5 mm) for functional radionuclide imaging is provided by positron emission tomography where volume estimates are accurate to 10% for volumes down to 2 ml. Other non-γ emitting radionuclides such as ^{32}P and ^{89}Sr for systemic therapy require different non-imaging methods of dose estimation using haematological data.

Risk and benefit in systemic radionuclide therapy

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Systemic radiotherapy is now applied to a limited range of pathologies. As with any other situation in which radiation is used, the basic principle of protection, *i.e.* justification of the procedures as a form of therapy, must be applied. Part of the justification process must include an audit of the total detriment, potentially associated with the therapy, over a lifetime of follow-up. This paper attempts to evaluate the benefits and risks of the three most common forms of systemic radionuclide therapy within this framework.

Teach-in: Pitfalls in Abdominal Computed Tomography

Chairman: Dr A. K. Dixon

General problems in abdominal computed tomography
A. K. Dixon
Pitfalls in computed tomography of the upper abdomen
R. H. Reznek
Errors in abdominal computed tomography: how to reduce them
A. K. Dixon, S. Stephens and I. R. Martin

General problems in abdominal computed tomography

Adrian K. Dixon
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Many of the pitfalls in computed tomography of the abdomen are related to technique. The most common problem is inadequate bowel preparation; it is always better to err on the side of giving too much oral contrast medium rather than too little. Delayed images may prove very helpful when unopacified bowel hinders interpretation. Certain anatomical features lend themselves to misinterpretation and some of these are discussed. The female pelvis can be a particularly difficult area and the reasons for this are outlined. Residual masses following certain forms of therapy pose other problems; knowledge of the expected patterns of tumour response is helpful in these cases.

Pitfalls in computed tomography of the upper abdomen

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Pitfalls in interpretation of computed tomography (CT) are considered and illustrated in the following categories: (1) incorrect technique; (2) normal anatomical variants; (3) range of normality; and (4) failure to appreciate the limitations of the technique. Incorrect technique can include the following causes. Poorly opacified bowel loops may result in "pseudotumours" of the pancreas or mesenteric "masses" and inadequate distension of the stomach may lead to apparent thickening of the gastric wall. Inappropriate use of intravenous contrast medium can also cause confusion; administration of too much intravenous contrast medium can obscure filling defects in the renal pelvis, too little contrast medium can result in failure to characterize a cavernous haemangioma. Incorrect timing of the scan following intravenous contrast medium can result in laminar flow defects within the inferior vena cava, simulating thrombus. Insufficiently narrow collimation can exaggerate the partial volume effect and cause confusion in characterizing mass lesions. The importance of modifying the technique to certain clinical situations is illustrated. Normal anatomical variants, such as a persistent left inferior vena cava, large gonadal vein or large diaphragmatic crus, can all be confused with lymph node enlargement. The wide range of normal appearances can also result in confusion. For example, the pancreas changes markedly with age, being diffusely bulky in the young to atrophic in the elderly. Over-interpretation of the anatomical abnormalities detected by CT can be misleading. Although occasionally some lesions may have a diagnostic appearance on CT, in many instances it is not possible to deduce their histology. An example of this is the pancreatic mass lesion which can be due to neoplastic or inflammatory disease.

Errors in abdominal computed tomography: how to reduce them

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In broad terms, errors are either due to poor observation or incorrect interpretation. In a series of errors reviewed at our institution, these two types occurred with approximately equal frequency. In this series, errors were disproportionately common amongst female patients and some possible reasons for this are discussed. Errors are by no means confined to small lesions; indeed, large lesions can prove very difficult to interpret, especially the organ of origin. In this series, a roughly similar proportion of errors were made by senior and junior radiologists. Although informal dual reporting is widely practised in our institution, it is likely that more formal dual reporting would help prevent errors of observation; it should also assist interpretation.

Obstetric Ultrasound

Chairman: Dr M. Bark

The management of ante-natal diagnosis of fetal abnormality: the district and general hospital radiologist's role
I. Shirley
Referral for antenatal echocardiography
D. Crawford
Referral for antenatal surgery
C. Rodeck

The management of ante-natal diagnosis of fetal abnormality: the district and general hospital radiologist's role

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The increasing application of obstetric ultrasound makes new demands of radiologists with the necessary skills. As the experience of ultrasound-trained radiographers increases, so does the number of possible fetal abnormalities detected by routine scanning. The radiologist in charge must develop systems whereby suspect scans are repeated as soon as possible to allay maternal anxiety in normal cases and to enable diagnosis where appropriate. Precise diagnosis of abnormality requires scanning skills and knowledge of the possible spectrum of abnormality in each case. In particular, associated anatomical anomalies or abnormal fetal karyotypes may require investigation. The radiologist will be able to co-ordinate such investigations by establishing links with obstetric colleagues and specialist departments. Some anomalies, for example, those of the renal tract, will require follow-up by the radiologist during the pregnancy and in early post-natal life when further radiological studies may be required. This is facilitated by the relationship which the radiologist will have established with the parents. The final role for the radiologist lies in quality control of the service. Monitoring of personnel and equipment performance is necessary. Systems to correlate scan findings with outcome must be developed. This paper examines the role of the district and general hospital radiologist in these various areas.

Referral for antenatal echocardiography

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Congenital heart disease (CHD) affects eight per 1000 of livebirths of which two per thousand may be detected by routine ultrasound screening (Allan et al, 1986). The prognosis for cardiac anomalies detected *in utero* is poor. A recent study (Crawford et al, 1988) reported 83% mortality in continuing pregnancies 1 year after antenatal identification of CHD. The optimum time for imaging the fetal heart is generally 20–22 weeks gestation. Similar quality images can be obtained at 18 weeks gestation if high-resolution equipment (5 MHz) is available. The "four chamber view" can be used as an effective screening technique for the most severe anomalies (anomalies detectable: two per 1000 livebirths). Examination of the arterial connections should be included as part of a referred anomaly scan (3.5 per 1000). All cardiac connections, ventricular and atrial septa and cardiac valve function will be studied at the specialist cardiac referral centre (five per 1000). Our experience indicates that obstetric ultrasonographers can learn to recognize many normal features of cardiac anatomy. Those pregnancies in which an abnormal anatomy is suspected may then be referred for further evaluation. The specialist referral centre will provide: (i) accurate diagnosis of the cardiac defect; (ii) detailed counselling on the long-term prognosis, corrective or palliative surgery currently available; (iii) further investigations appropriate for individual anomaly; and (iv) transfer of antenatal care can be arranged when appropriate. When referring a patient it is important to explain to the family that a serious problem is suspected. Over 80% of anomalies are confirmed and the detailed information offered during counselling is better understood by the patient and her family if they are not in shock. To assist radiologists skilled in the examination technique but with a limited experience of the spectrum of fetal congenital heart disease, a videotape of the study may be sent to the specialist for a second opinion.

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Referral for antenatal surgery

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Abstract not received.

Angiography and Cardiac Radiology: proffered papers and posters

Chairman: Dr W. D. Jeans

The role of transluminal angioplasty in the management of femoro-distal graft stenosis
J. Sheridan, J. Thompson, V. Gazzard, S. Birch, M. McShane, J. Webster and T. Chant
Review of percutaneous renal artery angioplasties performed at Hammersmith Hospital between 1980 and 1988
M. E. Roddie and D. J. Allison
What level of residual pressure gradient following iliac angioplasty affects the outcome?
D. J. Tawn, S. Armstrong and W. D. Jeans
Attitudes to angioplasty: results of a survey of the Association of Vascular Surgeons of Great Britain and Ireland
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Role of low-dose streptokinase therapy in the management of acute lower limb arterial and graft occlusions
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Thrombolysis in peripheral arteries and bypass grafts
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Local streptokinase for acute lower limb ischaemia: is distal run-off important?
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Right-sided aortic arch and congenital heart disease revisited
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Experience with 30 subjects using cine magnetic resonance imaging to evaluate the heart
R. M. MacMillan, W. F. Muhr, P. A. Ross, J. Murphy, K. Chandrasekaran, J. Callahan and M. E. Haskin
Does cine magnetic resonance imaging underestimate left ventricular volume?
R. M. MacMillan, K. Chandrasekaran, J. Y. Kresh, J. H. Murphy, J. L. Callahan and M. E. Haskin
Randomized trial of coronary angioplasty after thrombolysis: assessment of left ventricular function
P. J. Thorley, K. L. Sheard, I. Wilson, A. F. Mackintosh and M. R. Rees
A new method for detection of acute myocardial infarction using ^{111}In-antimyosin antibody imaging
D. Jain, A. Lahiri, U. Raval, J. C. W. Crawley and E. B. Raftery
Reconstruction of three-dimensional single photon emission computed tomographic thallium cardiac scans: an aid to diagnosis?
H. Dexter

The role of transluminal angioplasty in the management of femoro-distal graft stenosis

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Femoro-distal graft stenosis occurs frequently and may rapidly progress to graft failure. To assess the incidence of stenosis, 206 patients were studied. Duplex scanning and ankle-brachial systolic indices were measured 1 month after operation and then at 3-monthly intervals thereafter. Duplex identified 22 stenoses in 175 grafts which completed serial analysis. All stenoses were confirmed on angiography; only five were symptomatic. Indications for intervention were a fall in the ankle-brachial systolic index of >0.2 or a high-grade stenosis on duplex scanning. Treatment was surgical revision or percutaneous transluminal angioplasty. An initial success rate of 100% was confirmed on angiography and duplex scanning. Results show that five of six proximal graft stenoses revised surgically remain well, and suggest that long-term results of surgical revision are superior to angioplasty.

PTA	Proximal	Intragraft	Distal
Recurred (6 months)	3	5	7
Satisfactory (18 months)	0	1	0

Review of percutaneous renal artery angioplasties performed at Hammersmith Hospital between 1980 and 1988

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Since its introduction, percutaneous transluminal renal angioplasty (PTRA) has been established as an effective method for treatment of renovascular hypertension. Although the outcome varies somewhat between different centres, there is, in general, agreement with respect to the effects on blood pressure (BP). In atherosclerotic (AS) stenoses, cure or improvement of BP is achieved in 60–80% of patients while this figure reaches 80–90% with fibromuscular hyperplasia (FMH) stenoses. Apart from the treatment of elevated BP, preservation or improvement of renal function may result from PTRA. The reported incidence of major complications directly related to PTRA varies from 2 to 10%. We have reviewed all patients who underwent PTRA in our department to see how our results compared with those published in the literature. Since 1980, 65 PTRAs have been attempted in 45 patients. The population included 33 patients (73%, mean age 58 years) with AS, eight patients (17%, mean age 34 years) with FMH, two patients (4%, mean age 46 years) with vasculitides and two patients (4%, mean age 37 years) with transplanted kidneys. In four patients with AS it was not technically possible to cross the lesion. Hypertension in the patients with AS was cured or improved in 59% while in the patients with FMH the figure was 88%. In patients with vasculitis it was cured in 50% of cases and in patients with transplanted kidneys it was cured in 100%. In patients with impaired renal function, PTRA resulted in normal renal function or improved renal function in 64%. Major complications, directly related to PTRA, occurred in 8% of arteries angioplastied. These consisted of three occlusive dissections of the renal artery requiring urgent surgical revascularization and two ruptured balloons which required arteriotomy for removal. Minor complications occurred in 10% and consisted of one non-occlusive renal artery dissection, two minor dissections of the aorta, two large groin haematomas, one of which required blood transfusion, and two cases where the patient experienced severe pain during inflation of the angioplasty balloon. We conclude that our results in terms of BP reduction and improvement are similar to those quoted by other centres. Assuming that our technique does not significantly differ from that used in other institutions, our high major complication rate may be due to our patient population or possibly to under-reporting of complications in the literature.

What level of residual pressure gradient following iliac angioplasty affects the outcome?

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Iliac angioplasties in which pre- and post-dilatation pressure gradients were recorded, performed between 1 January 1984 and 31 December 1987, were reviewed. Seventy-six angioplasties were performed in which the gradient across the lesion was recorded, but 25 of these patients were lost to follow-up or died, leaving 51 cases for review. Thirty-nine angioplasties (76%) were successful in abolishing the patients' symptoms and 12 (24%) were failures, with recurrence of symptoms within 12 months of the procedure. A group of eight patients had a residual gradient across the lesion of 20 mmHg or more. Of these, four (50%) were unsuccessful. The remaining 43 patients had a residual gradient below 20 mmHg, and in the majority it was abolished. There were eight failures (19%) in this group. Therefore, it is apparent that a residual gradient of 20 mmHg or more across an iliac lesion following angioplasty is associated with a greater incidence of failure of the procedure.

Attitudes to angioplasty: results of a survey of the Association of Vascular Surgeons of Great Britain and Ireland

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We circulated the 266 member of the above society to assess the numbers of angioplasties performed for peripheral vascular disease during 1987. The availability, indications and types of lesions treated have been analysed. Of 178 (66.9%) replies, 70 (39.5%) were from teaching hospitals and 107 (60.5%) from district hospitals (one respondant was excluded as they only performed renal angioplasty). Of the 169 (95.5%) who referred patients for percutaneous transluminal angioplasty (PTA), 74 (43.8%) also carried out intraoperative angioplasty. One hundred and thirty-three (89.9%) sometimes used a combination of proximal PTA and distal surgery. Eight (4.5%) did not request PTA, mainly because of lack of suitable equipment or radiological expertise, and wanted the procedure to be available in their hospital. The median numbers of angioplasties carried out on patients under the respondents' care in 1987 were 11–20 percutaneously and 1–10 intraoperatively. Percutaneous transluminal angioplasty was judged to be the first-line active treatment for stenotic vascular disease <10 cm in length above the inguinal ligament by 122 (70.5%) surgeons (below the inguinal ligament 71 (41.3%)). The clinical indications for angioplasty and types of angiographic lesions treated are discussed. Percutaneous transluminal angioplasty was considered to have more complications than surgery as follows: proximal stenoses 17 (9.8% of respondents), proximal occlusions 61 (37.7%), distal stenoses 55 (32.1%), distal occlusions 79 (48.5%). Ninety-four (53.7%) required claudicants to stop smoking before PTA and 106 (63.9%) stated that the introduction of angioplasty had definitely increased the numbers of patients referred for angiography.

Role of low-dose streptokinase therapy in the management of acute lower limb arterial and graft occlusions

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Emergency surgery for acute lower limb arterial or graft occlusion can be hampered by the inability to obtain accurate pre-operative arteriography. The idea that thrombolysis by low-dose intra-arterial streptokinase would allow an angiographic diagnosis and so more appropriate intervention has some merit. This concept was tested in 26 patients (12 native arteries and 14 grafts) with acute lower limb arterial or graft occlusion. Twelve patients (seven arteries and five grafts) had complete lysis of thrombus and in all cases it was possible on subsequent angiography to demonstrate an underlying arterial or graft abnormality. Following intervention, the long-term results in the native arteries were very good but the long-term results in the grafts were disappointing. Delay in intervention was associated with a poorer result. Ten patients suffered complications including two cerebrovascular accidents and one death. This study emphasizes the role of streptokinase in allowing more accurate pre-operative diagnosis, and also the contraindications and complications of treatment.

Thrombolysis in peripheral arteries and bypass grafts

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Low-dose intra-arterial streptokinase infusion is an established method for treating thrombotic occlusions of lower limb arteries and bypass grafts in patients presenting with symptoms of lower limb ischaemia. However, the results in occluded bypass grafts are variable. It has been suggested that patients with plasma fibrinogen levels less than 1 g per litre are at greater risk of haemorrhage. Newer agents are said to have a lower rate of systemic complications but are considerably more expensive. A randomized clinical trial of low-dose intra-arterial streptokinase infusion compared with surgical management of a selected group of patients presenting with severe lower limb ischaemia is in progress. Components of the fibrinolytic system are being monitored to predict complications. The initial results are presented which indicate that thrombolytic therapy is a worthwhile and cost-effective first-line treatment, particularly if an underlying cause is identified and treated.

Local streptokinase for acute lower limb ischaemia: is distal run-off important?

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Over the last 30 months, 38 patients (29 male, nine female, mean age 65 years, range 38–85 years) have undergone streptokinase therapy for acute lower limb angioplasty (II) and post-femorodistal bypass (III).

Arterio-graphic run-off	Acute on chronic ischaemic (I)	Post-angio-plasty (II)	Post-femoro-distal bypass (III)	Overall
Good				
Success	7	5	4	16
Failure	0	4	2	6
Poor				
Success	0	0	0	0
Failure	8	3	5	16

Run-off was a significant discriminant in the acute on chronic ischaemia group (I) ($\chi^2 = 11.25, p < 0.001$) and in the overall group ($\chi^2 = 17.2, p < 0.001$). The early and late mortality rates were 7.9% and 10.5%. In Groups I and II, a successful outcome was only achieved in those patients with good run-off on arteriography. Four failures in the presence of good run-off were due to intimal dissection (2) and haemorrhage (2), respectively. Streptokinase infusion was unsuccessful in femorodistal grafts which occluded within 30 days of operation. In four grafts that occluded after 1 month, streptokinase therapy was successful in all cases. Long-term patency was achieved by a combination of surgery and balloon dilatation. These figures suggest that local streptokinase infusion works best if there is adequate distal run-off. The most encouraging results are in patients with acute on chronic ischaemia and following late occlusion of femorodistal bypass grafts.

Tissue plasminogen activator in peripheral arterial thrombolysis

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Thirty acute peripheral arterial thromboses in 28 patients have been treated with local low-dose intra-arterial recombinant tissue plasminogen activator (r-t-PA). All patients received 0.5 mg/h r-t-PA; in addition, 15 patients received 250 units/h of intra-arterial heparin. Overall limb salvage at 30 days was 83% (25/30). Despite successful lysis of an acute iliac thrombosis, amputation was still required in one patient because of established gangrene. Mean ankle/brachial index was increased by 0.53 ± 0.26. There was no significant difference in these parameters between the two groups, although there was a trend towards a longer duration of therapy in the heparin group (32 ± 18 h) than with r-t-PA alone (26 ± 13 h) (NS). No strokes or major haemorrhages occurred. Minor haematomas associated with the catheter entry site occurred in four (13%). There were four deaths (13%) from documented myocardial infarctions occurring between 5 and 21 days following treatment. Re-thrombosis occurred in four (13%) cases. In the two patients following r-t-PA alone, these occurred after 2 and 11 days. Limb salvage was achieved with a successful repeated thrombolysis (1) and a femoro-popliteal graft in the other. Re-thrombosis following concurrent therapy with low-dose heparin occurred in two patients after 30 days because of poor run-off (1) or extensive proximal atheromatous disease (1). Continued experience has confirmed r-t-PA to be a safe, effective thrombolytic agent when given as a low-dose intra-arterial infusion. The addition of low-dose heparin has not produced any significant benefit and has probably contributed to a tendency to a longer duration of therapy.

A comparison of indium-111 platelet deposition following different peripheral arterial thrombolytic regimes

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Streptokinase (Sk) and recombinant tissue plasminogen activator (r-TPA) have widely different effects on platelet aggregation. We have therefore undertaken a prospective evaluation of indium-111 platelet deposition following peripheral arterial thrombolysis. Nineteen patients were studied using autologous indium-111 labelled platelets. Ten patients had received 0.5 mg/h intra-arterial r-TPA(IA), and seven patients received 5000 units/h Sk +250 units/h heparin intra-arterially. Two further patients received r-TPA intravenously(IV) at 2 mg/h. All patients received 18 MBq indium-111 within 24 h of the completion of thrombolytic therapy, whilst on a standard dose of heparin. Imaging was performed at 24, 48 and 72 h. Initial uptake ratios at 24 h were usually low for all three agents (mean values: Sk 1.17; r-TPA(IA) 1.29; r-TPA(IV) 0.64), despite previous angioplasty or extensive thrombosis. There were higher uptake ratios following Sk (1.17; 1.63; 1.65), than with intra-arterial r-TPA (1.29; 1.04; 1.46) which were not significant. Following r-TPA(IV), significantly higher ratios ($p < 0.05$) were seen compared with either Sk (24 and 48 h) or intra-arterial r-TPA (48 h). Overall, four patients failed to achieve complete lysis (three) or incurred early re-thrombosis (one). All were associated with a progressive increase in uptake ratio over the study period, which was significantly higher ($p < 0.05$) after 72 h than those deemed to be successful. These early results suggest that r-TPA(IA) may be associated with a reduced risk of re-thrombosis than Sk. Significantly higher platelet deposition was seen with early re-thrombosis or failure to achieve complete lysis. Concurrent therapy with antiplatelet agents may therefore be indicated in these patients.

Contrast agents, coagulation and the angiographer

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The interactions between iodinated radiological contrast agents and various elements of the blood have hitherto been of only academic interest. Recently, however, authors in Scandinavia and in the United States have suggested that the non-ionic contrast agents are more strongly associated with, or are more likely to engender, both disordered red cell aggregation and frank clotting in syringes and catheters contaminated with blood than are the ionic agents. The spectre of accidental embolization of patients has been raised and this has resulted in considerable anxiety among angiographers in the United States. Our knowledge of contrast agent–blood interactions is reviewed and the practical implications objectively assessed.

The influence of pH on the stability of red blood cell aggregates resulting from contamination of various contrast media with human blood *in vitro*

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Concern has recently been expressed about the formation of red blood cell aggregates when contrast media are contaminated with blood *in vitro,* and the potential risk of injecting such aggregates into patients during angiography. Data are presented demonstrating the influence of pH on the stability of these red cell aggregates when both conventional ionic contrast media and the newer non-ionic contrast media are contaminated with human blood. These findings are discussed with respect to the influence of the local physico-chemical environment on the interaction between contrast media and red blood cells, and the potential consequences of this for angiographic procedures.

Transcatheter embolization of vascular lesions in the external carotid arterial tree

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Vascular malformations and tumours in the head and neck pose a difficult therapeutic problem. Surgery is technically difficult and ligation of the main feeding arteries may result in the lesion receiving its blood supply from other more inaccessible vessels, making further surgery or embolization technically difficult if not impossible. We present our experience of embolization of vascular lesions in the external carotoid arterial tree. Sixty-four procedures have been performed on 46 patients. Thirty-nine patients had vascular malformations, the remaining seven patients had vascular tumours. We describe the indications for the procedure, the technique employed and the possible complications. Two of the patients with vascular malformations had plastic surgery after embolization, the remainder have been treated by embolization alone. Of the seven patients with vascular tumours, four had surgery after embolization reduced the vascularity of the lesion and three had such a good response to embolization that surgery was not necessary. We suggest that embolization should be the initial treatment of choice in vascular malformations with a prominent arterial component. It may be the only form of treatment necessary in the majority of cases. Patients with vascular tumours may also benefit from embolization as an adjunct to surgery or, in some cases, it may be the only treatment necessary.

Complications of high brachial artery puncture

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High brachial puncture has been described as an alternative route of arterial access when femoral catheterization is not possible. In Sheffield this technique has been used since 1986. Fifty-two procedures have been performed in 51 patients. Follow-up was obtained in 48 patients (49 procedures). The artery was catheterized in the mid upper arm using a single piece needle, an 0.035 in guide wire and a 5-gauge pigtail catheter in all but three procedures (6- or 7-gauge catheter). The procedure was successful in 43 cases. All studies were non-selective. The following complications were observed. Twelve patients had significant haematomas (large in five) but no intervention was required. In four patients the radial pulse was absent at the end of the procedure. Three patients had no associated ischaemic problems, the pulse returning spontaneously within 24 h, although remaining chronically reduced in one patient. Another patient developed ischaemia of the left arm with paraesthesiae immediately following the procedure. A 5 cm occlusion of the brachial artery was demonstrated. This was successfully treated with immediate angioplasty with resolution of the symptoms and no long-term deficit. Paraesthesiae in the median nerve distribution were noted in a further two patients, both recovering spontaneously. Axillary artery puncture may be complicated by brachial plexus damage. No significant neurological problems and only one major vascular complication were observed in this study. The complications observed appear similar to those of brachial artery puncture at the elbow. High brachial puncture appears to be a safe alternative when femoral puncture is not possible.

Right-sided aortic arch and congenital heart disease revisited

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The incidence of a right aortic arch in various congenital cardiac lesions has been well documented in the past, but some reports do not agree with subjective impressions of the frequency of this abnormality. To determine whether there had been a change in the incidence of right aortic arches, we reviewed 900 consecutive cardiac angiograms from a 5-year period. The frequency with which a right-sided arch occurred in association with each type of congenital heart disease was recorded. The incidence of the right-sided aortic arch in our study is compared with that quoted in a major radiological textbook (*Diagnostic Radiology* ed. R. G. Grainger and D. J. Allison, 1986, Churchill Livingstone, Edinburgh) which is given in parentheses. The incidence was very similar in pulmonary atresia and VSD: 28% (25%); Fallot's tetralogy: 26% (25%); and transposition of the great arteries: 3% (<5%). There were significant differences in other abnormalities: truncus arteriosus 21% (30–50%) and tricuspid atresia 3% (10–20%). In some conditions the association was not specified or recognized, but in our study was double-outlet right ventricle (18%), single ventricle (14%), pulmonary stenosis with VSD (6%) and solitary VSD (3%). A review of the presenting chest radiographs showed that it may be difficult to assess the side of the aortic arch, as the right-sided arch was clearly visible in only 70% of cases and appeared to be left–sided in 10%. The frequency of right-sided aortic arches in some congenital cardiac abnormalities differs in our survey from that suggested in general radiology textbooks. This might reflect a change in incidence, a change in diagnostic criteria or an improved survival from some of the more severe defects. Whatever the cause, the incidence of this abnormality varies with time and between populations.

Diagnosis of aortic dissection using echocardiography and computed tomography

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The diagnosis of aortic dissection should be made rapidly, accurately and by the least invasive method. Recent reviews conclude that angiography remains the investigation of choice in these patients. In our hospital it has been policy since 1986 to investigate all such patients with urgent echocardiography and rapid-sequence, contrast-enhanced computed tomography (CT). During this period, 22 patients presented to the Department of Radiodiagnosis with suspected aortic dissection. All patients were examined by echocardiography and by CT in 20. The results of the two investigations were analysed jointly. There was no need to resort to angiography to obtain a diagnosis in any of the cases. In two cases echocardiography alone was adequate. Nineteen of the 22 patients were diagnosed as having aortic dissection, three had no evidence of dissection on echocardiography or CT. Seventeen of the 19 with dissections were Daily Type A; 10 of these had surgery which confirmed ascending aortic tears, five were treated conservatively (three of these had the diagnosis confirmed at MRI, two had no further investigation) and two died shortly after investigation before surgery could be performed. Two patients with Type B dissection had no further investigations. In no case did the result of surgery, post-mortem examination or subsequent follow-up change the diagnosis given by echocardiography or CT (the minimum period of follow-up being 8 months in patients without surgical or post-mortem confirmation). Until recently, angiography has been the investigation of choice for aortic dissection. We feel that our results indicate that patients with suspected aortic dissection can be accurately investigated with echocardiography and CT. These combined investigations are a suitable, less invasive alternative to conventional aortography, which can be used without loss of diagnostic accuracy.

Experience with 30 subjects using cine magnetic resonance imaging to evaluate the heart

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Cardiac cine MRI was performed on 30 consecutive subjects using a GE 1.5 T Signa scanner. Multilevel ECG-gated cine was obtained at 16 images/cardiac cycle. Images were 10.5 mm thick and the data acquisition time per sample was 33 ms. The effective TR was 66 m and TE 17 ms. Images were obtained in axial, sagittal, coronal, long- and short-axis planes. Twenty-seven subjects had cardiac catheterization (cath), 22 had echocardiography (echo) and 18 had radionuclide ventriculography (RNV). Left ventricular (LV) volumes and ejection fraction (LVEF) were obtained by biplane cath and cine MRI one day apart in 18 subjects. Correlations (r) were: LV end-diastolic volume ($r = 0.94$), LV endsystolic volume ($r = 0.96$) and LVEF ($r = 0.85$). Left ventricular ejection fraction measured on the same day by MRI and RNV in 14 subjects were correlated ($r = 0.91$). Left ventricular volume regional wall motion was compared (both normal or abnormal) for MRI versus cath, echo and RNV. There was agreement for MRI vs cath in 21 out of 25 (84%), MRI vs echo in 18 out of 21 (86%) and MRI vs RNV in 14 out of 18 (78%) cases. Right ventricular dimension and function were in agreement for echo vs MRI in 15 out of 15 cases (normal in 13; abnormal in two). Mitral regurgitation (MR) was compared (both present or absent) for long-axis MRI vs cath and long-axis MRI vs echo. There was agreement for long-axis MRI vs cath in 13 out of 13 cases (100%) with four of 13 having MR. For long-axis MRI vs echo there was agreement in 12 out of 15 cases (80%). Aortic regurgitation (AR) was found in the same three of 13 subjects by long-axis MRI, echo and cath, with complete agreement in 13 out of 13 cases for all three techniques. Intracardiac shunts were demonstrated in three subjects by cath and MRI. We conclude cardiac cine MRI is a useful adjunct to spin–echo MRI in providing data on cardiac dynamic function.

Does cine magnetic resonance imaging underestimate left ventricular volume?

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Cine magnetic resonance imaging (MRI) using a G.E. Signa 1.5 T scanner was used to measure left ventricular volumes (LVV) and ejection fraction (EF) in 12 patients (mean age 58 years). Images were acquired in the short axis and slice thickness was calibrated at 10.5 mm. The data acquisition time per sample was 33 ms, effective TR = 66 ms and TE = 17 ms.

End-diastolic (ED) and endsystolic (ES) images were selected for each contiguous slice through the left ventricle. Endocardial-cavity edge was defined by setting a window width of 1 and selecting the minimum level maintaining continuity of the interventricular septum. The same level setting is used for ED and ES images for a single slice but may vary between slices. Volumes of each slice were summed to obtain EDV and ESV. Biplane LVV and LVEF were measured at catheterization (cath) 1 day after MRI. Same-day gated blood pool radionuclide (RNA) LVEF was measured in eight patients. A significant correlation was found between MRI and RNA LVEF: ($r = 0.96$, $p < 0.0005$). A significant correlation was found between cath and MRI volumes: EDV ($r = 0.89$, $p < 0.0001$), ESV ($r = 0.93$, $p < 0.0001$) and LVEF ($r = 0.85$, $p < 0.0005$); MRI volumes underestimated cath volumes by 21%. Using a fixed human heart of known LVV imaged in the short axis, MRI consistently underestimated absolute volume by 17%. We conclude, with use of a correction factor, cine MRI can accurately measure LVV and LVEF in man.

Randomized trial of coronary angioplasty after thrombolysis: assessment of left ventricular function

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Patients who had streptokinase infusion within 4 h after myocardial infarct were randomized into two groups. One ($n = 42$) had PTCA 48 h after thrombolysis. The other group ($n = 41$) acted as a control having conventional medical therapy. At 3 months post-infarction all patients were studied using ^{99}Tc^{m}-gated blood pool scintigraphy (MUGA). Left ventricular function was assessed from the ejection fraction together with a semiquantitative wall motion score. Wall motion was assessed in five segments with four grades of abnormal motion: mildly hypokinetic, hypokinetic, akinetic and dyskinetic. A large range in ejection fractions (8–87%) was observed but the difference in the mean ejection fraction between the two groups was not significant: PTCA group, 60 ± 13% (mean ± SD); control group, 57 ± 19%. No significant difference was found in the wall motion abnormality score or in the number or site of abnormal segments. It can be concluded that PTCA at 48 h has no effect on ventricular function when measured at 3 months. The effect of angioplasty on long-term ventricular function is being assessed by follow-up studies at 12 and 18/24 months. Initial results indicate no significant difference between the two groups at 12 months.

A new method for detection of acute myocardial infarction using ^{111}In-antimyosin antibody imaging

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One hundred and twenty-three patients admitted with suspected acute myocardial infarction (AMI) or unstable angina (UA) were entered in a study to evaluate the role of ^{111}In-labelled antimyosin antibodies (In-AM) for the diagnosis of AMI. Out of 117, in whom adequate images were available (four died prior to imaging and in two images were technically inadequate), 74 had AMI (Q-wave AMI in 53 and non-Q in 21), 16 had unstable angina and 27 had neither, based upon the standard ECG and enzymatic criteria. All patients with Q-wave AMI had positive images (sensitivity 100%), 20 out of 21 with non-Q-wave AMI had positive images (sensitivity 95%), seven out of 16 (28) patients with UA had positive images, and in patients with neither, two out of 27 had positive images. In-AM imaging has a positive predictive value of 91% and negative predictive value of 97% for the detection of AMI. In seven patients with AMI with raised enzymes but with negative ECG, the infarction was correctly identified by In-AM imaging. In those with UA, six out of seven patients with positive images had adverse cardiac events (sudden death in two, urgent revascularization for control of symptoms in four). In-AM administration was safe and did not produce any antibody response. Images were of good quality and easily interpretable. This imaging technique can be used for the direct visualization of the necrotic myocardium in patients in whom diagnosis of AMI is in doubt using conventional methods. This technique has significant advantages over ^{99}Tc^{m} pyrophosphate imaging where the specificity is limited and image clarity is obscured by sternal and rib activity.

Reconstruction of three-dimensional single photon emission computed tomographic thallium cardiac scans: an aid to diagnosis?

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The size and distribution of myocardial infarcts are compared using conventional single photon emission computed tomographic thallium images and three-dimensional reconstructions. A videotape demonstration of the results is shown.

Teach-in: Preparation of a Scientific Paper or Report

Chairman: Dr N. J. McNally

Papers for publication
J. T. Patton
Preparing a radiological medico-legal report
J. O. M. C. Craig
How not to present a paper
A. E. H. Emery

Papers for publication

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This paper covers the following points. (1) The importance of having a clear idea of the purpose of the paper. Unless this is clear in the mind of the author, it is easy to be side-tracked by subsidiary issues, not strictly relevant to the main point which may only reduce the power of the paper. It is worth while writing this down so that if unexpected but interesting facts come to light during analysis of the work, one should then decide whether they should be included as something enhancing the original message, or made the subject of a separate paper. (2) The advantages and possible disadvantages of adhering to the conventional formula of Abstract, Introduction, Materials and Methods, Results and Discussion, and Conclusions, and consideration given to the temptation to break away and use a more personal format. (3) The technique of committing the work to paper: when to use pen, typewriter, word processor, etc. (4) Style: the importance of adhering to a journal's "house style" and how far should one go in imprinting one's own literary skill on to a scientific paper? (5) The avoidance of jargon and vogue words, while recognizing the consequent risk of a turgid style with pedantic adherence to traditional forms of syntax. (6) The importance of a title and the advantage of a short, easily remembered one. (7) The desirability of having the manuscript vetted by a colleague, not necessarily a specialist in that field, who may find parts of the material difficult for the uninitiated to understand. (8) How much of the above can one leave to the Editor, having regard to the over-riding importance of getting the message published.

Preparing a radiological medico-legal report

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There are many types of medico-legal report, but this paper considers two. (1) Accident cases: issuing a radiological report concerning injuries. This is most often after bony injuries and mostly for insurance purposes. (2) Medical litigation: passing an opinion regarding a claim for negligence. This may concern a radiological procedure, a particular radiological technique or a radiological diagnosis. Attention to detail is crucial for any radiologist issuing a written report to a legal body. In the case of an accident case and insurance claims, the radiological findings are often factual, although a differential diagnosis may arise. For cases of medical litigation, great care is needed and an unbiased opinion is sought in duty to both the patient and the medical staff involved. An expressed radiological opinion needs to be based on a knowledge of the definition of negligence, a detailed knowledge of all the circumstances of the incident, the experience of those involved, and the accepted practice at the time. These points are considered in this paper.

How not to present a paper

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Important factors in giving a lecture include the appearance of the lecturer, the actual delivery, and the manner in which material is presented. Each of these topics is discussed and illustrated where appropriate!

Imaging in Organ Transplantation

Chairman: Dr G. I. Verney

The renal transplant: full of sound and fury?
P. Dubbins
Radiology of liver transplantation: the first 20 years
J. B. Karani
Heart and lung transplantation: shadows of the truth
T. W. Higenbottam
Change of heart — change of image
G. I. Verney, H. Davies, T. A. H. English and J. Wallwork

The renal transplant: full of sound and fury?

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In the 30 years since the first successful renal transplant was performed, renal transplantation has become widely accepted as the best treatment for end-stage renal failure. While many aspects of patient preparation, surgical procedure, post-operative management and immunosuppressive maintenance have been significantly improved over this period, other problems remain. Transplant failure may be due to vascular compromise, hyperacute rejection, acute tubular necrosis and urinary outflow obstruction in the early post-transplant period. Later, renal function may be compromised by renal artery stenosis, acute or chronic rejection, cyclosporin A toxicity or the development and progression of underlying renal disease. The management of these conditions requires vastly different therapy — acute tubular necrosis, for example, requiring purely supportive therapy; acute rejection, increased immunosuppression; cyclosporin A toxicity, reduced cyclosporin dose; and mechanical problems, surgical intervention. If treatment of the complications of renal transplantation is to be effective then accurate diagnosis is essential. The intravenous urogram has little or no place now in the management of transplanted kidneys and contrast studies are restricted to antegrade pyelography in hydronephrosis, usually secondary to compromise of the ureteric anastomosis. Much hope had been expressed for many of the rather more modern imaging techniques. Indeed, many of the early reports using ultrasound imaging, radionuclide imaging, duplex Doppler and more recently MRI, yielded incredible figures for sensitivity and specificity of the individual techniques in differentiating between acute tubular necrosis, rejection and cyclosporin toxicity. With time, however, has come caution. As more reports appear, so overlaps between different diagnostic groups are shown by any and all of the diagnostic modalities. It is not surprising perhaps that there should be difficulty in distinguishing, for example, cyclosporin A toxicity and acute rejection since both may show an interstitial mononuclear cellular infiltrate, and there may be occasionally tubulitis in both as well as cells in the peritubular capillaries. It is therefore necessary to be somewhat circumspect in the assessment of claims and counter claims for the accuracy of individual imaging techniques. The approach to diagnosis of complication of renal transplant should therefore follow a practical and cost-effective algorithm. While multiple investigations may have superficial attraction, there is scant evidence that when performed in "battery" fashion that diagnostic accuracy is increased. Indeed, the degree of confusion may be increased instead. All diagnostic algorithms depend upon local availability of equipment and expertise. Our practice, however, is to perform early ultrasound examination in renal transplant failure. Real-time ultrasound can be performed quickly and at the patient's bedside. The grey-scale image achieved gives information about presence or absence of hydronephrosis, complication by lymphocoele or other fluid collection, as well as certain morphological characteristics suggestive of acute rejection. When combined with a Doppler device as in duplex systems, vascular patency and integrity can be confirmed. Moreover, Doppler flow spectral characteristics provide information which is probably related to the internal cellular or vascular pressure within the intrarenal substance. Any pathology increasing the intrarenal pressure will increase the resistance to blood flow and this would be reflected in the Doppler shift frequency spectrum derived from the main and branch renal arteries. While early work suggested that this was specific for acute rejection, it is now clear that there is some overlap with acute tubular necrosis and similar features may also be seen in cyclosporin A toxicity. In our practice, if clinical and ultrasound findings support a diagnosis of acute rejection or acute tubular necrosis, etc., then the patient is managed accordingly. If, however, there is doubt or disagreement then dual radionuclide studies using technetium-99m DTPA to assess the perfusion phase and ^{131}I-hippuran for assessment of tubular function may be successful in differentiating renal transplant pathology. The management of the renal transplant requires close co-operation between surgeon, renal physician, radiologist and pathologist. Imaging techniques are of great value in the diagnosis of transplant complications, but none achieves ideal levels of sensitivity and specificity. Therefore, whilst it would be unreasonable to state that imaging investigations in the evaluation of renal transplants are full of sound and fury but signify nothing, no individual test provides all the answers. A workable diagnostic algorithm is proposed that uses widely available diagnostic techniques effectively and economically to provide maximum diagnostic yield.

Radiology of liver transplantation: the first 20 years

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Orthotopic liver transplantation is now the treatment of choice for end-cell liver stage failure. Although the first liver graft operation was carried out in March 1963, it was not until July 1967 that the first operation with prolonged survival was achieved in that same group. The Cambridge/King's College Hospital programme was established in May 1968 and has now carried out over 500 liver transplants. These 20 years have seen a steady increase in the number of patients treated and on the current programme over 100 patients are transplanted per annum. Improved survival can be attributed in part to judicious patient selection, with radiology playing a critical role in this decision. This is particularly important in patients with previous surgery or with liver tumours where very accurate vascular and tumour mapping are necessary. Post-operatively, the majority of patients require only limited radiological assessment with ultrasound, but in those patients with biliary or vascular complications, the interventional arm of radiology may be required. The overall results of liver grafting are discussed, highlighting the role of radiology.

Heart and lung transplantation: shadows of the truth

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Combined heart and lung transplantation (HLTx) is a successful treatment of severe pulmonary vascular disease, end-stage chronic lung disease and cystic fibrosis. The major problem now concerns the after-care of patients. It had been believed that endomyocardial biopsy could diagnose rejection but from clinical and experimental studies the lungs undergo rejection before the heart (McGregor et al, 1985). Diagnosis of rejection has depended on clinical criteria, but, unfortunately, symptoms and signs of lung infection are indistinguishable. This difficulty has probably contributed to the high incidence of chronic lung rejection in early series of patients (Burke et al, 1986). At Papworth we have used prospectively transbronchial lung biopsies (TBB) through a fibreoptic bronchoscope and this is both specific and sensitive in diagnosing lung infection and distinguishing it from rejection (Higenbottam et al, 1988). Retrospective analysis of the first 45 episodes of rejection revealed that in the 1st month after surgery the chest radiograph was abnormal in 74% of rejection episodes, whilst later than 1 month, 32% of radiographs were abnormal. Furthermore, it was not possible to distinguish lung rejection from infection on radiography. In both, diffuse pulmonary shadows occurred often with right sided pleural effusion.

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Change of heart—change of image

G. I. Verney, H. Davies, T. A. H. English and J. Wallwork
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In 10 years from January 1979 over 300 heart transplants have been performed at Papworth Hospital. The indications, management, results and complications are briefly reviewed. The role of plain radiographs, endomyocardial biopsy, transbronchial biopsy and percutaneous needle biopsy in the management of the early complications of rejection and infection are discussed and illustrated. Late non-cardiac complications related to immunosuppression, lymphoproliferative disease, osteoporotic fractures and avascular necrosis in bones have been uncommon. They do not differ from other groups of immunosuppressed patients. Apart from the first 29 patients, all management protocols have included cyclosporin and as with other groups this has been associated with a significant incidence of renal disease and hypertension. Before the transplant programme started at Papworth, worldwide experience was already indicating that the most important life-threatening complication was coronary artery disease. The main emphasis of this paper is to report the findings of routine coronary and left ventricular angiograms initially carried out annually but latterly carried out at 2 years and 4 years and annually after that. In the 8½-year period from August 1980, over 300 such studies have been carried out on 140 patients and the varying radiological appearances are presented. The pattern of the obstructive disease found tends to show a significant difference from that seen in "ordinary" ischaemic heart disease and these are illustrated and discussed in the light of the orthodox risk factors and in the light of the varying treatment protocols. Correlation of the angiographic findings with the post-mortem findings in a few patients who died within a short period of an angiogram has confirmed that angiography tends to underestimate the disease present and also an apparently normal-looking coronary tree does not exclude arterial disease. The role of angiography in relation to re-transplantation and the assessment of left ventricular function in this group of patients are also discussed The limited role of percutaneous transluminal balloon angioplasty is described, as is the role of radionuclide scintigraphy. For the future, hopes that non-invasive techniques may be able to replace or reduce the indications for catheterization are discussed. They remain "on the agenda" but so far have not been realized.

Presidential Address

"Limitations on a theme"

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When radiologists speak of interpreting radiographs they dismiss in a phrase an act of enormous complexity. Compared with the effort directed to the development of new imaging techniques, study of the interaction between the observer and image has been relatively neglected and there is insufficient appreciation of the limitations of human performance in this regard. The spatial frequency model of vision provides us with a clear appreciation of the physiological constraints to vision in the perception of fine detail and provides a rationale for the use of magnification, altered viewing distance and spatial frequency filtration of images. Recent demonstration of a pre-attentive process in vision which can inspect (in parallel) complex textures over the whole visual field is of great relevance in radiology where figure/ground separation and texture discrimination are important in diagnosis. The radiological task is concerned, in essence, with the acquisition, organization and use of knowledge, activities which are more commonly subsumed within the province of cognitive psychology. Cognitive science is a discipline which has a long past, with roots extending back to classical times, and yet a short history in having emerged as a new paradigm in psychology after the Second World War. The central unifying concept is that human cognition can be explained in terms of models employing computational processes which are applied to symbols, consisting of internal representations of the world. Research techniques and recommendations from studies in visual search, pattern recognition, memory and vigilance studies are eminently applicable to radiology. For example, the cognitive limitations to computer-assisted diagnosis, such as the problem of unambiguously codifying image descriptors, require to be addressed. The principal factors which limit an observer's capacity to process data derived from radiological images include our limited memory capacity, our selective rather than comprehensive abstraction of data, our inability to integrate a great deal of information simultaneously, and the fact that our inevitable simplification of judgement tasks introduces bias into decision making. Research in this area is directed towards answering two questions; first, what are the activities involved in reporting radiological images and what constraints are there to observer performance? and secondly, what does learning radiology consist of? The answer to these questions clearly bears on our understanding of reporting errors and on improving our technique for effective radiological teaching, and here we may anticipate the development of "intelligent" textbooks of radiology.

Contemporary Issues in Uroradiology

Chairman: Dr H. B. Meire

The role of ultrasound in paediatric urinary tract infections
R. de Bruyn
Imaging in chronic renal disease
P. Allan
Imaging the prostate
D. Rickards
Intravenous urography or ultrasound in prostatism
P. Dubbins

The role of ultrasound in paediatric urinary infections

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In the early 1980s it was suggested that ultrasound may replace urography in the screening of paediatric patients with uncomplicated urinary infections. The controversy continues to this day. The case for ultrasound as the primary initial investigations is strong, provided its limitations are recognized. Urinary tract infection is a common condition yet we do not want to over-investigate children with unpleasant and potentially hazardous investigations. The aim of initial screening is to identify these children with surgically remedial causes, for instance, congenital anomalies such as post-urethral valves obstructing drainage, duplex systems, megaureters and urinary calculi. However, it is necessary to identify those children at risk of renal damage from vesico-ureteric reflux. This is where the major controversy lies. The known facts about vesico-ureteric reflux are: (1) scarring usually occurs within the first year of life and probably within the first 6 months; (2) renal scarring is therefore usually present at presentation with a urinary tract infection; (3) renal scarring is often progressive; and (4) it rarely develops after the age of 4 years in a previously normal kidney. The role of ultrasound in vesico-ureteric reflux, renal scarring, the small kidney, duplicated ureters and the assessment of the bladder and posterior urethra in males is considered and discussed. Ultimately, all children after the first proven urinary tract infection should undergo investigation. We suggest that ultrasound should be that first examination.

Imaging in chronic renal disease

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Patients with chronic renal disease can be divided into three broad categories: those in chronic failure, those on dialysis, and those who have received a transplant. Plain radiographs, contrast studies, ultrasound, computed tomography, radionuclide studies and angiography can all be used in the assessment of these patients to a greater or lesser degree. In practice, plain radiographs of the chest and skeletal system, together with ultrasound examination of the kidneys/transplant are the most frequently used examinations for routine assessment, the other imaging modalities being reserved for complications of the original renal disorder or its treatment. The development of the techniques of magnetic resonance imaging and Doppler ultrasound over recent years and their widening sphere of clinical applications should provide further methods for assessing patients with chronic renal disease. It is apparent that the native kidneys of patients with end-stage renal disease are not simply inert, fibrotic lumps which can be ignored. Proliferative changes leading to the development of cysts, adenomas and, on occasion, carcinomas occur in many of these patients. Although these changes can be seen in patients prior to dialysis, they are much more prevalent in patients on dialysis (both haemodialysis and continuous ambulatory peritoneal dialysis). They can also be seen in transplant patients but their prevalence seems to be lower, although the reasons for this are not yet clear. The problem persists in diagnosis of patients with failing transplants, especially in distinguishing between acute tubular necrosis and vascular rejection; cyclosporin toxicity is another possibility which must now be considered in this situation. Radionuclide studies and ultrasound imaging contribute to differentiating between these problems and duplex ultrasound provides further information on blood flow which may allow their distinction in many cases.

Imaging the prostate

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Until ultrasound (US) and computed tomography (CT) were available, the prostate was imaged indirectly. It rapidly became clear that transabdominal ultrasound had little to offer and CT was of limited use except in looking for nodal disease associated with prostate cancer. In imaging the prostate itself, transrectal ultrasound (TRUS) and magnetic resonance (MR) are the current front-runners. Transrectal ultrasound has caused much controversy over the past 5 years and its technology continues to expand apace with the development of new endoprobes. Magnetic resonance in this country is still of limited availability, but TRUS is not. On this basis, discussion of prostate imaging must centre around TRUS. There have been many reports of the appearances on TRUS of prostate cancer that have been both conflicting and confusing. The consensus of opinion is that prostate cancer is a predominantly echo-poor lesion, but can be isoechoic with normal prostate tissue in up to 25% of cases. Transrectal ultrasound is accurate in locally staging disease, but the necessity to stage is debatable. As a screening tool, TRUS shows promise. Benign and inflammatory disease can also be diagnosed on TRUS, as their appearances are better defined; TRUS can also be of immense value in assessing outflow obstruction. Magnetic resonance is able to resolve the internal structure of the prostate and its role in cancer is being studied in many centres. Magnetic resonance will have a significant role to play once more widely available.

Intravenous urography or ultrasound in prostatism

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Historically, the elderly male presenting with voiding symptoms of hesitancy, poor stream, frequency, urgency and nocturia has received as part of his investigation, an intravenous urogram. In the past the justification for this examination was to provide information on bladder disorders, prostate size, renal function and diseases of the upper urinary tract. Changes in medical practice, however, demand a reappraisal of the role of the intravenous urogram in patients with prostatism. Bladder disorders, prostate size and urinary obstruction are better evaluated by cytoscopy, transrectal ultrasound and urodynamic techniques. Indeed, some authors have now returned to a more traditional view, that even urodynamic studies should be reserved for specific indications, most patients being judged on the severity of their clinical symptoms. It is, after all, on the basis of resolution of symptoms that the success of the operative technique will be judged. The rationale, therefore, for retaining intravenous urography in the investigation of prostatism can only be in the assessment of upper urinary tract disease. However, renal function is better evaluated by serum creatinine and urea, and in those patients found to be azotaemic, ultrasound is a better technique for the evaluation of renal size, parenchymal texture and hydronephrosis. The only indication that remains for intravenous urography as a screening technique in patients with prostatism is in the evaluation of upper tract tumours. The validity of such a policy depends on detection of significant numbers of tumours and, particularly, detection at a stage when these are treatable. Combining all the existing series evaluating intravenous urography in patients with prostatism, the overall prevalence of renal cancer (including renal cell carcinoma and urothelial tumours) is 0.4%. Whilst this appears higher than the underlying incidence of renal carcinoma in the elderly male population (less than 0.01%) it is difficult to justify an investigative technique with such a low yield, particularly when other procedures with similar sensitivity are available. Moreover, in patients of this age, the incidence of simple renal cysts is high and the detection of renal mass lesions by intravenous urography demands the further investigation of more than 20% of the patients with ultrasound. If an investigation for upper urinary tract disease is required as a screening procedure, then ultrasound would seem to be the investigation of choice. It allows the evaluation of renal obstruction, chronic pyelonephritis and the differentiation of these from other causes of uraemia, as well as the detection and characterization of renal mass lesions. Furthermore, it allows the accurate assessment of the residual volume of urine within the bladder and other bladder abnormalities. It is possible, perhaps indeed likely, that a number of transitional cell tumours would be missed by this technique but unless it is considered reasonable to screen the entire male population over 60 years for transitional cell tumours, their incidence in patients with prostatism does not justify the expenditure, the risks associated with contrast media, or the cost to the community resulting from absence from work because of lengthy investigative procedures. In an era of containment there is an argument for restricting investigation of patients with prostatism to a simple blood sample and cystoscopy at the time of transurethral resection of the prostate, unless symptoms, signs or biochemical findings suggest a need for other investigation. If any imaging modality is to be used as part of the screening procedure, then there is an overwhelming case for the procedure to be ultrasound on the basis of cost, diagnostic yield and the non-invasive nature of the technique. The intravenous urogram has outlived its usefulness in the investigation of prostatism but refuses to lie down!

Calibration and Clinical Dosimetry in Brachytherapy

Chairman: Mr R. Blackwell

Dose specification in intracavitary therapy
  C. A. F. Joslin
Definition of dose and traceability to a standard source
  A. Dutreix
Source calibration within individual departments
  T. J. Godden
Problems of consistency and dose intercomparison between centres using brachytherapy
  D. I. Thwaites and J. R. Williams
Dose distribution and methods of determining dose to critical organs in brachytherapy
  J. M. Wilkinson

Dose specification in intracavitary therapy

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A major issue in brachytherapy is the problem of dose and volume specification. While the concepts of target volume, treatment volume and irradiated volume can be used in a manner analogous to external-beam therapy, the specification of target absorbed dose becomes difficult. A further difficulty occurs when treatment with external-beam therapy is planned. The early "systems" of prescribing treatment were dependent upon the source strength used, the geometrical distribution of the sources and time of application. The move to a point source definition by the Manchester system introduced the concept of prescribed dose to a standard point in relation to a number of standard source configurations and loadings. While this sufficed for many years, changes have occurred which necessitate a further appraisal based on: (i) the replacement of radium; (ii) SI units; (iii) advances in tumour imaging technology and target volumes becoming easier to define; (iv) computer-assisted planning programmes providing for dose distribution systems in several planes; and (v) new technological developments providing for greater manipulation and control of source positions and dwell times. These changes provide for a replacement of the time–activity concept with a time–dose concept qualified by a defined reference volume, enclosed by a given isodose with a full history of the time–dose pattern used as it relates to the reference air kerma.

Definition of dose and traceability to a standard source

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Since the beginning of the century most of the brachytherapy applications have been performed with radium sources. The strength of the sources was expressed in milligrams of radium. The applications were first specified by the duration of the application, and later on by the product of the total mass of radium and of the time (milligram hours). However, radiotherapists and physicians in Manchester have developed a dosimetry system in which the number of milligram hours could be determined from the prescribed dose expressed in roentgens. The advent of the modern sources of artificial radionuclides, as well as the necessity to adopt the international system of quantities and units, forces radiotherapists and physicists to adopt new quantities to express the strength of the sources as well as the dose delivered to the patient. National and international bodies agree to express the strength of sources used in brachytherapy in terms of the product of kerma rate in air and the square of the distance at which it is expressed. The proposed unit is the μGy h^{-1} m^2. The International Commission on Radiation Units and Measurements has proposed that this quantity be named reference air kerma rate. The traceability from the dose at a point to a standard source includes the description of all the factors used in dose calculation and the different steps leading to source calibration. The factors used in dose calculation, apart from the distance, are linked to shape and size of the source, to radiation filtration by the inactive sheath, to attenuation and scattering by tissues and to the ratio of the mean mass absorption coefficient in water and in air. The large uncertainty attached to the exposure-rate constant or the kerma rate constant is eliminated when using the reference air kerma rate instead of the activity.

Source calibration within individual departments

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In the calibration chain which ensures consistency in prescribed dose in brachytherapy techniques from one radiotherapy centre to another, each department must carry out various checks on the sources prior to use and at regular intervals thereafter. The initial checks must include measurements to ensure that the source strength is as specified by the manufacturer on the Test Certificate supplied with the sources or source trains. The methods employed to establish the validity of the Test Certificate, which are dependent upon the physical form and activity of each source, are reviewed. Pitfalls in the use of the validated source strength data for routine work are discussed and potential sources of error in determining the dose within a patient from such data are highlighted.

Problems of consistency and dose intercomparison between centres using brachytherapy

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The revival of interest in brachytherapy in recent years has included a re-emphasis on clinical trials involving brachytherapy, as shown by discussion at the ICTRO developmental conference reported recently (*International Journal of Radiation Oncology, Biology, Physics, 14*, 1988, Suppl. 1). At the same time, quality assurance of radiotherapy generally has assumed an even greater importance. There is a need therefore to quantify uncertainties in dosimetry in brachytherapy and to identify areas of imprecision, in order to both improve the situation and allow confident comparisons of clinical results based on confidence in dosimetry and its consistency. In addition, because combinations of brachytherapy with external-beam radiotherapy (or comparisons of brachytherapy against external beam) are of interest, there is a need for adequate absolute accuracy to be achieved, as well as adequate precision for consistency's sake. All factors involved contribute to total uncertainty. Some areas where inconsistency arises are briefly discussed. These include: source specification, standards and traceability; variation in specification statement by the supplier; check calibration of supplied sources by the user; realization of the treatment situation and determination or reconstruction of the treatment geometry; calculation of dose distribution, including physical parameters and corrections, as well as algorithm employed; dose prescription, selection and specification by the clinician, bringing in differences in dosimetry/treatment systems, as well as treatment volume specification and dose homogeneity considerations; biological corrections, and variation of geometry, etc. throughout treatment. Some *a priori* estimates of the uncertainties in brachytherapy have been made, which are reviewed and reassessed. Some limited intercomparisons have been carried out at various points in the dosimetry chain for brachytherapy. These are also reviewed and discussed. Suggestions are made for possible dosimetry intercomparisons, as part of the on-going IPSM Radiotherapy Dosimetry Intercomparison. Particular problems for brachytherapy intercomparisons are outlined and suggestions are made for improving and maintaining consistency in brachytherapy.

Dose distribution and methods of determining dose to critical organs in brachytherapy

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For several years, patients undergoing intracavitary brachytherapy at the Christie Hospital have been selected for computed tomography and detailed investigation of the pelvic dose distribution. The scanning is performed after the insertion of the afterloading applicators and an isodose display is superimposed on the cross-sectional images. The two isodose lines displayed correspond to the prescribed dose and to half the prescribed dose. A feature of brachytherapy, which is obvious from the displays, is the very high dose gradient at all points that may be regarded as clinically significant. Generalized statements about, say, tumour dose, bladder dose or rectal dose are, therefore, not meaningful without further qualification. The prescribed dose, such as the dose at Point A, will represent the minimum dose on the surface of a considerable volume of potentially tumour-bearing tissue, but the rectal dose, for example, could represent the maximum on the rectal mucosa, or that at some predetermined reference point, or a measured dose which is unlikely to be either! By adopting a systematic approach and defining a prescription point, such as Point A, in a reference geometry, individualized calculations relating to prescribed dose are avoided, but critical organ doses are specific to individual patients. The reason for determining critical organ dose is to predict an unacceptably high risk of causing serious complications, but it is not obvious which is the important parameter. For example, is it (a) the maximum dose to the bladder mucosa, (b) the dose at a particular point in the bladder or (c) the area of bladder mucosa exceeding a particular dose, that most reliably predicts bladder damage? Methods of seeking an answer to this type of question are presented and some of the practical difficulties that are encountered are discussed.

Teach-in: Pitfalls in Paediatric Chest X-ray Films

Chairmen: Drs R. K. Levick and H. Carty

No abstracts received.

Physics Equipment and Techniques: proffered papers and posters

Chairman: Dr R. Shields

An investigation of the accuracy and precision of dynamic processes measured by magnetic resonance imaging
F. Valeh, M. Halliwell, P. C. Jackson and P. N. T. Wells
The use of the hyperbolic secant pulse to improve nuclear magnetic resonance longitudinal relaxation time measurements using the inversion–recovery/saturation–recovery sequence
P. Gowland, M. O. Leach and J. C. Sharp
High-resolution fluorography: initial clinical evaluation
R. F. Bury and P. James
Quantitative comparison of tissue ablation by excimer laser: comparison of normal biliary tree with cholangiocarcinoma
M. E. Roddie, L. S. Machan, C. S. Foster, P. T. Rumsby and M. C. Gower
Random errors in thyroid iodine concentration measurements by quantitative computed tomography
J. E. Damilakis and N. S. Karkavitsas
The assessment of image quality by spatial frequency analysis
B. S. Worthington, A. G. Gale, Y. Y. Bakir and N. Russell
A quantitative comparison of velocity waveforms obtained in the common carotid artery using magnetic resonance phase imaging and Doppler ultrasound
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A simulation of blood flow and pH heterogeneity in tumours
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Ultrasound quality assurance: use of commercial test instruments
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Quantification of iodine mass in digital subtraction angiography
M. T. Arnold and D. J. Hawkes
Reduced dose in chest radiography
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Extremity doses during interventional radiology
R. J. Aukett, M. J. Dunn and K. Palmer
Gauss: a generalized approach to updating scanner strategies
A. E. Bacon, S. McKenzie, M. Smith, J. Bingham and M. Bramer
Low-cost image storage using a personal computer and optical disk
A. Parkin, H. M. Norwood and A. J. Hall

An investigation of the accuracy and precision of dynamic processes measured by magnetic resonance imaging

F. Valeh, M. Halliwell, P. C. Jackson and P. N. T. Wells
Department of Medical Physics, Bristol General Hospital, Bristol

The quantification and dynamic behaviour of fluids *in vivo* is relatively unexplored. Magnetic resonance imaging (MRI) has demonstrated the potential of generating angiographic images non-invasively and the possibility of quantifying fluid dynamics. It is likely that the development of MRI flow techniques and measurements will allow improved clinical assessment, particularly in those situations in which blood vessels are inaccessible to Doppler flow techniques. Using phase-sensitive imaging, this study was undertaken to investigate the accuracy, reproducibility and limitations of velocity and flow measurements. These included flow in different size vessels and orientations as present in the body. For this purpose a constant-flow phantom rig consisting of different diameter tubing was used. The diameter sizes were chosen to simulate the size of the arteries in the body. Velocity measurement estimations in major abdominal vessels were investigated in clinical studies and compared with Doppler ultrasound measurements. As a better approximation of the true *in vivo* situation, a pulsatile phantom will be developed. Work will also be undertaken to assess the effects of turbulence and non-laminar flow on the accuracy of velocity measurements.

The use of the hyperbolic secant pulse to improve nuclear magnetic resonance longitudinal relaxation time measurements using the inversion–recovery/saturation–recovery sequence

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Nuclear magnetic resonance (NMR) imaging techniques are being developed for the measurement of relaxation times *in vivo* with a view to monitoring response to therapy in cancer patients. It has been shown in the literature that the interleaved saturation–recovery/inversion–recovery sequence is a very efficient method of measuring T_1. We have modified this sequence by including a hyperbolic secant pulse in order to effect the slice selective spin inversion. This pulse gives a flat inversion profile to within 3% across the slice, compared with 20% for a sinc pulse, and is relatively insensitive to variations in pulse amplitude. As a result the signal after the 90° pulse is primarily dependent upon the inversion time (TI) as there is no variation in pulse angle across the slice. Measurements were performed on a set of calibrated gel phantoms having a T_1 range of 226–1621 ms using a 1.5 T Siemens Magnetom NMR system. Sequence timing parameters of TR = 4.0 s, TI = 1.3 s were used to measure samples having a long T_1, and these values were changed to TR = 3.0 s, TI = 1.0 s for samples having an intermediate T_1. The band width of the hyperbolic secant pulse was optimized to twice that of the 90° pulse; this was 15% lower than the band width of the corresponding sinc inversion pulse otherwise required. Preliminary results have shown that T_1 greater than 500 ms can be measured to an accuracy of better than 2% using the hyperbolic secant pulse, compared with 7% using a conventional sinc pulse. The calculated random error was small (1%); however, both the long- and short-term reproducibilities were measured as <3%. Phantom results over the whole T_1 range are presented, together with details of preliminary *in vivo* measurements. Further work is being carried out on improving the precision of the sequence.

High-resolution fluorography: initial clinical evaluation

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We present the first results of high-resolution fluorography (HRF) using a unique image intensifier. This incorporates a thin (50 μm) input phosphor, as opposed to the more usual 100–150 μm layer, in an attempt to improve spatial resolution. It is linked to a fluorography camera and mounted underneath a floating-top table. The 100 mm hard copy was reported by two radiologists (R.F.B. and P.J.) using a standard viewing box and a hand lens, recording in each case the diagnostic adequacy of the radiographs, and whether magnification was needed. The study was designed to assess the viability of HRF as a possible replacement for film–screen techniques, both as a stand-alone system and as a potential "front end" for the digital department of the future. A separate study has objectively evaluated the HRF equipment described here, using accepted criteria of contrast performance, unsharpness and noise. Our results, on the other hand, reflect the subjective impression of the radiologist at the viewing box, as it is this which will ultimately determine the acceptability of any new technique in routine use. The first 300 examinations are reviewed. Diagnostically acceptable results were achieved in well over 90% of cases in spite of initial difficulty in adjusting to small film format. For most examinations acceptability approached 100%. The advantages of replacing film–screen techniques with HRF are discussed as are the disadvantages of the prototype apparatus used here, which would preclude its use as a stand-alone system. We feel that our experience fully justifies further development work with the manufacturer.

Quantitative comparison of tissue ablation by excimer laser: comparison of normal biliary tree with cholangiocarcinoma

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Cholangiocarcinoma represents only 1% of all malignancies but, because of its anatomical site, it presents a considerable therapeutic problem. It is a potentially resectable tumour but in up to 75% of cases, depending on its site, curative surgery is not possible. In these patients palliation can be achieved by external or internal biliary drainage. The latter, achieved by placing an endoprosthesis across the malignant biliary stricture, avoids the problems of cholangitis, bile leakage and tube dislodgement. However, in up to 20% of patients the lesion cannot be crossed and endoprosthesis insertion is not possible. A method of delivering ablative energy to safely create a channel through an obstructive cholangiocarcinoma would allow more patients, whose tumours are not amenable to surgery, the benefit of internal drainage. We present experimental results on the excimer laser cutting quality and rate using specimens of normal bile duct and cholangiocarcinoma. Three different laser wavelengths, 193, 248 and 308 nm were used and for each wavelength the cutting rate (microns per pulse) was measured at different beam intensities. Analysis showed that there was no significant difference in cutting rate between normal bile duct and cholangiocarcinoma at the two lower wavelengths. However, at 308 nm the cutting rate for bile duct was significantly lower than for cholangiocarcinoma over all beam intensities. These results show that there is a differential energy absorption between bile duct and cholangiocarcinoma at 308 nm. Therefore there is a potential role for excimer laser, delivered via a conducting fibre, in tumour debulking prior to endoprosthesis insertion.

Random errors in thyroid iodine concentration measurements by quantitative computed tomography

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In thyroid disorders, various abnormalities in iodine metabolism can cause differences in the iodine concentration of the gland. Quantitative computed tomography (CT) has made it possible to eliminate the iodine levels of the thyroid *in vivo*, by using the linear relationship between CT number and thyroid iodine concentration. However, although quantitative CT is already used in the assessment of various diseases, there are several effects that produce errors, which limit the reliability of studies. We have investigated the random errors in thyroid iodine concentration measurements introduced by (1) scanner instabilities, (2) different ROI shapes and sizes, (3) relocalization of ROI by the same and different operators, and (4) repositioning the patient. We used a reference phantom simulating the neck at the level of the thyroid gland. Comparing values obtained in a patient with those obtained in the phantom, the negative effects of scanner instabilities can be reduced, and calibration in iodine concentration (mg/ml) is achieved. The use of different ROI positions, shapes and sizes yields significantly different results. In the case of inhomogeneous patterns, the largest possible ROI is needed in order to have a small magnitude of error. Performance of ROI relocalization and selection by the same, rather than different, operators offers improved reproducibility. The error in repositioning the patient is found to be low. Our results indicate that the use of a reference phantom and localization has to be performed very carefully by the operator.

The assessment of image quality by spatial frequency analysis

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An objective method of evaluating radiographic images is illustrated which relates the spatial frequency content of the image to the performance of the human visual system. This has its highest sensitivity to low contrast at 3 cycles/degree with a response up to 50 cycles/degree but only at high contrast. Assessment of the information content contained in any selected sample of an image can be achieved by examining the spatial frequency components contained within its density profile. An analogue density function is obtained by scanning with a microdensitometer and this is then Fourier analysed giving a frequency spectrum. The area under the graph obtained by plotting the root mean square value of the amplitude against spatial frequency is a function of contrast, geometrical unsharpness and the degree of noise present. This data can be used to compare images of the same object obtained under different conditions and also provide an index of image quality. Furthermore it can be used to indicate whether the eye–brain system is likely to perceive the whole information contained on the radiograph. The use of this method to compare the performance of different mammographic systems in imaging a test phantom is illustrated and the results compared with those of a subjective assessment of the smallest image detail perceived using each system and an ROC analysis of test radiographs. A further study compares the quality of the mucosal images achieved using four commercial barium preparations in clinical practice with those in a model of the human stomach consisting of air-filled compartments in a plastic box each lined by pig gastric mucosa. Rating the images by the objective method showed a good concordance with a blinded assessment of mucosal detail in clinical studies using a linear analogue scale.

A quantitative comparison of velocity waveforms obtained in the common carotid artery using magnetic resonance imaging and Doppler ultrasound

J. P. Ridgway, L. W. Turnbull, P. L. Allan, P. Hoskins and J. J. K. Best
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We have studied the common carotid artery in normal volunteers comparing velocity waveforms obtained using magnetic resonance (MR) phase mapping with the waveforms from Doppler ultrasound. Magnetic resonance phase imaging was performed at 0.08 T using a field echo sequence in which the slice select and readout gradient waveforms were modified so that accidental phase modulation due to constant velocity flow was minimized. Velocity-dependent phase encoding was achieved by shifting one of the slice select gradient pulses by 1.0 ms in one of two interleaved acquisitions. Phase maps were calculated for each acquisition and subtracted to produce an image coded for flow through the slice. This allows velocities of $\pm 120\ \mathrm{ms}^{-1}$ to be imaged before wrap-around occurs. The technique was calibrated using a continuous-flow phantom. Ungated multislice phase maps in the sagittal plane were used to determine the level of bifurcation in both carotid arteries. A transverse section was then prescribed 2 cm below the lowest bifurcation. The measurement sequence was cardiac gated and six to eight frames of 10 mm slice thickness were collected throughout the cardiac cycle using a TR of 120 ms. A 90° flip angle was used in order to maximize the signal from flowing blood. Three sets of images were acquired by altering the time delay of the first frame from the R-wave by 40 ms increments, so that between 18 and 24 frames were obtained for each patient study. A region of interest including the common carotid artery was defined interactively using the magnitude and phase images in which the vessel boundary was most apparent. Maximum and mean velocities were obtained by overlaying this region onto each frame. A background phase measurement was taken from a region of fat in the neck to account for any zero offset in the phase measurements. Doppler ultrasound (3 MHz) was performed immediately following the MR examination, while the volunteer remained supine. Doppler waveforms were recorded from the carotid arteries 2 cm below the bifurcation. The recorded waveforms were later analysed on a microcomputer and correlated with the maximum velocities measured by MRI. Maximum velocity waveforms obtained from the volunteers are presented showing good agreement between the two techniques in each case.

Measurement of human tissue *in vivo* nuclear magnetic resonance dispersion curves

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T_1 and T_2 relaxation-time measurements have been made on human subjects *in vivo* at six frequencies using 12 nuclear magnetic resonance (NMR) imagers throughout Britain, each operating at a fixed frequency. The same female subject and one of two male subjects were examined on each of the imagers. Other subjects were examined where time permitted. Transaxial sections were taken of the head at the corpus callosum level, the upper abdomen and the thigh. Several regions of the head images containing predominantly white brain or grey brain were examined, as were regions of liver, spleen, thigh muscle, thigh fat and femur marrow. Images of one of two phantoms (which differed only in size) were taken in head and body coils. T_1 and T_2 were found from regions of interest using the standard software of each imager. The test objects contained 2% agarose doped with seven different concentrations of manganese chloride to give T_1 values to cover the tissue range. After completion of the total series, small pieces of the agarose were measured at each imaging frequency in a precision, multi-frequency spectrometer at room temperature. A comparison of T_1 and T_2 values from the spectrometer and each imager gave a calibration curve which was used to calibrate the tissue values. Variation of T_1 within a particular region of an image is caused by tissue inhomogeneity or imager noise. Below 20 MHz the ratio of the percentage standard deviation of the T_1 and T_2 values of the tissue to those of the phantom was only 1 : 2 but the ratio rose to ~ 10 at high frequency. Some imagers produced T_1 and T_2 values for the phantoms which were very different from the calibration values, but, after correction, the plots of $1/T_1$ versus frequency were reasonably smooth and were similar to plots for rat tissues *in vitro*.

Differentiation of brain tumours by processing of computed tomographic images

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Integration of computed tomography (CT) into the differential diagnosis of intracranial space occupations requires a more efficient use of image information, either by developing more efficient signs for tumour discrimination or by measurement of quantitative features directly from digital image data. Spatial frequency spectra of tumour boundary structures are such a feature. For 139 patients with seven classes of the most frequent brain tumours, CT image data are taken from squares of 16 × 16 pixels centred in the tumour border. An appropriate set of features is derived from their Walsh spectrum and averaged for several of these square regions. Data and pattern recognition were assessed using linear discriminant analysis. We first compared the results with those obtained from a set of features containing image parameters measured on the evaluscope and anamnestic data. For both sets of features, similar classification rates of 57% (Walsh data) and 61% (patient and image data) were estimated for a single-step discrimination. Finally, a hierarchic classification system based on both sets of features was developed with an estimated classification rate (diagnostic accuracy) of 84%.

A simulation of blood flow and pH heterogeneity in tumours

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There is considerable interest in the potential of ^{31}P nuclear magnetic resonance (NMR) spectroscopy to determine the presence and degree of hypoxia in tumours. Intracellular hypoxia is an established determinant of radioresistance, the detection of which would provide an important indicator of therapeutic response. Intracellular pH may be an indirect indicator of tumour hypoxia because anaerobic glycolysis results in lactic acid production. Recent work has revealed discrepancies between previously published pH values in animals compared with humans. Whilst animal tumours are generally acidic, human tumours tend towards neutrality or even alkalinity. The reasons for these discrepancies may be the result of intrinsic differences between animal and human tumours. However, the ability to detect pH subpopulations *in vivo* may be limited by the sensitivity of whole-body NMR systems. This study investigates the probability of detecting a pH subpopulation in human tumours using a 1.5 T whole-body NMR system. A series of spectra were simulated, using a reference control population at pH 7.0 and subpopulations of differing pH. Both the proportion and pH of the subpopulation were varied. The model was based on known hypoxic and presumably acidic cell fractions in common tumours, with spectral resolution of 0.2 ppm. A range of levels of Gaussian noise was added to the simulated spectra. From the results of these simulations it seems unlikely that hypoxic, acidic fractions, typically of the order of 1–15% in human tumours, will be detectable by the method employed, which is only able to measure an average signal from the region of interest. Their presence is masked by the broad phospholipid baseline, the PME and PDE peaks and the P_i peak of the predominant cell population. Improvements in linewidth and sample signal-to-noise ratios are required to increase sensitivity. Implementation of recently developed localization techniques will improve linewidth and B_0 homogeneity over the volume of interest and exclude contamination from adjacent tissue.

Specification measurements on a multi-frequency imager

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The variation of image quality with static magnetic-field strength is of great importance when assessing the "optimum" magnetic resonance imaging frequency for different lesions and anatomical regions of interest. The Picker HP2055 whole-body system installed at Cambridge is capable of proton imaging at three field strengths (0.5, 1.0 and 1.5 T) and provides an excellent opportunity to investigate this problem. Physical parameters which affect image quality and subsequent interpretation are summarized and their influence on the design of suitable phantoms is discussed. Preliminary results of the variation of signal uniformity, signal to noise ratio, slice profile, geometric distortion, slice warp and resolution with field strength are presented. Consideration is given to the relevance of this work to clinical assessment of image quality, particularly when applied to the detection of intracranial lesions.

Ultrasound quality assurance: use of commercial test instruments

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In providing an imaging service it is essential to ensure that the equipment gives adequate performance. The setting up of the Ultrasonic Equipment Evaluation Project (UEEP) in 1985 using the Cardiff Test System and other test equipment has enabled an improved quality assurance service to be provided at district level. The UEEP reports list standard performance tests and results for a range of equipment. A selection of these tests are easily performed at district hospitals. In Leicestershire District, quality assurance is now mainly based on the following test equipment: (i) Cardiff Resolution Test object; (ii) Cardiff Grey-scale Test object; (iii) Acoustic Signal Injection System Tester; (iv) Digital Video Pattern Generator. The tests performed are illustrated. Common faults found include non-uniformity, lack of penetration and image recording problems. Sometimes despite satisfactory dynamic range the grey-scale characteristic may require adjusting for acceptable clinical performance. The following is concluded. (1) No order should be placed before an adequate technical specification has been provided. (2) All equipment should be carefully tested on delivery and test images filed for future reference. (3) Useful improvements could be made in the following areas: (a) the provision of reproducible test images for all imaging equipment in the service or operating manuals, and (b) a grey-scale tester for low-contrast performance.

Quantification of iodine mass in digital subtraction angiography

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In quantitative digital angiography and ventriculography it is necessary to correct for non-linear effects which distort the image contrast produced per unit mass thickness of iodine in the image. Subtraction removes errors due to non-uniformities and changes in the sensitivity of the imaging system, and to a large extent removes image structure arising from the presence of over- and underlying bone and soft-tissue features. Unfortunately, subtraction does not accurately compensate for effects such as X-ray scatter, veiling glare and beam hardening. Errors of 30–40% may arise in measuring the iodine content of a vessel or ventricle because of overlying bone or large changes in soft-tissue thickness. We propose a simple technique which involves taking an additional mask image with an attenuating filter mounted on the X-ray tube. A pixel by pixel correction image is synthesized from the mask images and this permits correction of these effects to a reasonable degree of accuracy. Using this technique we have reduced video densitometric errors by a factor of 5 in phantom experiments designed to represent a typical angiographic procedure. We believe that this calibration procedure is a vital first step to obtaining accurately calibrated angiographic images in analysis of blood vessel cross-sectional area, lumen geometry, the angiographic measurement of blood flow and the assessment of ventricular function by video densitometry.

Reduced dose in chest radiography

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In January 1988 a Philips Pulmo Diagnost 100 system for chest radiography was installed at Lewisham Hospital in London. This system, the first of its kind in this country, uses technology that is different from that used in conventional chest radiography. The Pulmo Diagnost 100 combines scanning slit radiography with a moving image intensifier, providing radiographs on 100 mm × 100 mm film. This reduces the quantity of scattered radiation from the patient and removes the need to use a secondary radiation grid. Estimates from the manufacturer indicate a large reduction in the radiation dose compared with conventional techniques. A comparison of the radiation dose was made between the scanning slit system and conventional high-kV chest radiography using a tissue-equivalent chest phantom and thermoluminescent dosemeters. Results are presented showing the reduction in the radiation dose to the patient obtained using the scanning slit system.

Extremity doses during interventional radiology

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Extremity doses received above lead aprons by persons performing interventional radiography, in particular cardiology, have been measured. The effects of dosemeter positioning have been assessed together with the impact of any reduction in the dose limits. Possible methods of dose reduction have also been investigated. The problems associated with the assessment of the contribution to the effective dose-equivalent from above apron doses are also discussed.

Gauss: a generalized approach to updating scanner strategies

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The work is concerned with the design of a maintainable knowlege-based expert system to advise on the selection of parameter settings for magnetic resonance imaging. The aim is to provide facilities for the medical expert to update the system, either to accommodate new research findings or to adapt it to his individual preference. The present system is designed in two parts; the expert system which advises on scan selection and the update module which enables changes to the knowledge base. A prototype system has been implemented on a Sun 3/60 computer using Prolog. The expert system incorporates a menu-driven interface to enable the input of clinical details such as suspected pathology and location; parameter settings for the recommended scan are calculated and returned to the operator. The update module incorporates facilities for making changes to the knowledge base. Provision is made for adding new facts and rules corresponding to the new diseases, imaging techniques and criteria for scan selection. Testing and debugging facilities are provided to ensure the integrity and correctness of the modified system.

Low-cost image storage using a personal computer and optical disk

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The wide range of imaging devices in routine use in diagnostic imaging departments generates large volumes of raw digital data which requires a large capacity, low-cost archiving facility. Floppy disk storage, which is often provided by the manufacturer for long-term storage of images, suffers from relatively high cost, a small number of images per disk and occupies a large amount of floor space. Optical disks have recently become available for use with industry compatible personal computers. They offer the benefits of large capacity (typically 800 MBytes), fast data access time, are cheaper than floppy disks (by a factor of ~20) and are much more compact. Transfer of data between the imaging device and optical disk poses problems as direct interfacing of the optical disk's personal computer to the imaging device is not usually possible since this may invalidate manufacturers warranty. The alternative approach of decoding the floppy disks generated by the imaging device is difficult, particularly if details of image storage format are not available. Our solution is to use the personal computer interfaced to a floppy disk reader to detect the beginning of file marker on the floppy disk from the imaging device. A sector by sector copy of this data is made onto the optical disk (without decoding) and the operator enters details of the file, including patient name, date and patient identifier, onto a conventional database which is held on hard disk. The database generates a reference pointer through which the file can be located. To retrieve the data the patient name and identifier is entered and the file is located and loaded into memory. It is then copied back onto floppy disk in the same format in which it was read. This disk can then be used at the viewing console of the imaging device. A detailed description of the system hardware and software is presented together with the operational procedure.

Management of Ovarian Cancer

Chairman: Dr R. J. Johnson

Radiology in the management of ovarian cancer
R. J. Johnson
An assessment of the accuracy of magnetic resonance imaging in the diagnosis and staging of suspected primary ovarian carcinoma
P. Hanley, B. S. Worthington, M. Powell and E. M. Symonds
Surgical management of ovarian cancer
J. Shepherd
X-ray therapy in the management of ovarian cancer
M. Adams and A. E. Brewster
Chemotherapy in the management of ovarian cancer
G. Blackledge

Radiology in the management of ovarian cancer

R. J. Johnson
X-ray Department, Christie Hospital, Manchester M20 9BX

Abstract not received.

An assessment of the accuracy of magnetic resonance imaging in the diagnosis and staging of suspected primary ovarian carcinoma

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Fifty-eight patients with suspected primary ovarian carcinoma were examined by magnetic resonance imaging (MRI) in at least two orthogonal planes employing a variety of T_1- and T_2-weighted pulse sequences and the short tau inversion–recovery (STIR) sequence. Ovarian cancer was confirmed in 32 patients at laparotomy; seven had metastatic disease in the ovary which was indistinguishable at surgery and 10 had a variety of benign ovarian tumours. The four primary bowel tumours, a chronic abscess, a liposarcoma, and three normal patients were correctly identified. Magnetic resonance imaging showed the solid and cystic component of tumours and the presence of haemorrhage; only occasionally, however, did the pattern allow the cell type to be suggested. Twenty-one out of the 32 patients were correctly staged by MRI as defined by the FIGO classification. As the examinations were confined to the pelvis and lower abdomen, all patients with surgical Stage IV disease were allotted to the MRI Stage III group. The presence of ascitic fluid in conjunction with a tumour was correctly identified in all cases. T_2-weighted and STIR images in the sagittal and transverse axial plane gave optimal demonstration of the bladder, rectum and pelvic side wall for which tumour involvement was demonstrated with an accuracy of 87%, 56% and 97%, respectively. Coronal inversion–recovery images were useful for showing serosal and omental metastases and ascitic fluid was particularly well shown on the modulus reconstruction variant. The principal shortcoming of MRI was the demonstration of bowel involvement, in particular peritoneal metastases, which were shown down to 1 cm in size but smaller deposits were missed. This limitation may be reduced with the advent of oral contrast agents.

Surgical management of ovarian cancer

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The diagnosis, staging and primary management of ovarian cancer remains surgical. The prognosis is dependent on all these factors. Three-quarters of epithelial tumours still present at an advanced stage after various non-specific symptoms, often related to the gastrointestinal tract. One-third of cases present to other specialist departments and many of these undergo initial surgery in non-gynaecological units. Surgical procedures are either primary or secondary and may be optimal or sub-optimal. Although correctly staged, Stage Ia epithelial tumours in young women wishing to retain their fertility may be treated conservatively with unilateral oophorectomy and careful follow-up; the majority of cases and those that are more advanced require radical oophorectomy. Tumour debulking, reducing residual disease to less than 1 cm in diameter, should be aimed for. Twenty-five per cent of cases will require a non-gynaecological surgical procedure, often bowel resection. Second-look surgery may assess the success of administering adjunctive chemotherapy but is only justified on a specific research protocol where management may be altered. It cannot be justified on other grounds as it does not improve survival or recurrence-free intervals. Secondary surgery may further reduce tumour bulk either for palliation or in an attempt to perform a salvage procedure when large tumour masses remain. Interval surgery after incomplete primary surgery followed by chemotherapy is of equivocal value. Follow-up after optimal surgery and first line chemotherapy may be with tumour markers (CA 125), careful CT scanning and monoclonal antibodies in association with clinical assessment. Second-line chemotherapy is rarely of value and radiotherapy is only of limited use in selected patients. In the future, intraperitoneal chemotherapy and targeted monoclonal antibodies may prove useful. Germ-cell tumours should be located by initial conservative surgery and then aggressive chemotherapy. They may be successfully monitored and followed in the majority of cases by tumour markers. Recurrence or persistent disease may require more radical surgical clearance. These tumours are, however, potentially curable. The prognosis of epithelial carcinoma has at last begun to improve in terms of increasing disease-free intervals and better 3- and 5-year survival rates. Most patients still die of their disease but their response is directly related to the extent of primary surgery and the volume of tumour remaining after completion of the first surgical attack.

X-ray therapy in the management of ovarian cancer

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The role of abdomino/pelvic radiation therapy and radioactive colloidal isotopes in ovarian cancer remains unclear. Whilst a curative role has been described in some patients, it has been confused by inadequate surgical staging and attention to prognostic factors (*e.g.* tumour grade). The relative merits of radiation and platinum chemotherapy in "early" disease remains unclear. The palliative role of local radiation in the relief of pain and bleeding in advanced diseases tends to be ignored. Current data does not prove a curative role for radiation therapy in patients with adequately staged Stage I disease and patients with Grade I and II Stage IIIa disease and Stage II with tumour residuum >2 cm have poor survival with such treatment. Whilst a curative role has been suggested for abdomino/pelvic radiation in Stage II disease with Grade II and III tumours in one controlled trial this is not supported by other data. The value of radiation in patients with Stage III minimal residual <2 cm or microscopic disease after response to platinum chemotherapy remains unproven. Results have been disappointing and bowel morbidity may be severe. A treatment scheme for "early" ovarian cancer is described and its role in the palliation of advanced disease described.

Chemotherapy in the management of ovarian cancer

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It is well established that chemotherapy is active in ovarian cancer. In non-epithelial ovarian cancer, combination cis-platinum-containing regimens are now responsible for a large percentage of patients achieving complete remission and cure. In epithelial ovarian cancer (EOC) the situation is different. Whilst cis-platinum regimens give response rates of up to 80%, with 30% complete remissions, few patients, if any, are cured as a result of chemotherapy. The role of chemotherapy is, therefore, to palliate the patient with EOC as effectively as possible, in association with other treatment modalities. Studies from the West Midlands and other centres suggest that maintenance chemotherapy is ineffective in prolonging remission. Patients with minimal residual disease after primary surgery have the best survival with chemotherapy, and trials are underway to determine whether chemotherapy can improve the less favourable prognosis of patients with bulky disease by cytoreducing the tumour prior to a definitive operation. The role of chemotherapy as adjuvant therapy in patients with no macroscopic disease following primary surgery has also not been established. No true trial of adjuvant treatment has yet been carried out, and this approach requires testing. In advanced (Stage IV) disease, the value of any treatment remains unproven. Encouraging results have been seen with some high-dose therapies, and these require further investigation. Finally, new compounds, such as biological response modifiers, and new access routes (intraperitoneal), have been developed. Studies are underway to determine whether these will represent a useful advance in the management of EOC.

Radiotherapy: proffered papers and posters

Chairman: Dr R. James

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L. Matheson, P. Tothill and K. McKay
An audit of head and neck cancer treatment in a regional centre for radiotherapy and oncology
A. Hong, M. I. Saunders, S. Dische, E. Grosch, D. Fermont, R. A. Ashford and E. J. Maher
A 12-year survey of soft-tissue sarcoma of childhood
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M. J. Lee, M. Teeling, D. Carney and E. Breatnach
Breast recurrence in young patients treated conservatively for breast cancer
D. A. L. Morgan, A. P. Locker, A. J. Moloney, I. O. Ellis, C. W. Elston and R. W. Blamey
In vivo ^{19}F nuclear magnetic resonance spectroscopy: human 5-fluorouracil pharmacokinetic comparison of intraperitoneal versus intravenous drug administration
J. Glaholm, D. Collins, B. Al Jehazi, M. O. Leach, V. R. McCready and H. O. White

The retention and distribution of platinum following the administration of cisplatin

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Measurements are being made of the concentration of platinum in tissues of experimental animals at various times after the infusion of 2.5 mg/kg body weight of cisplatin (cis-diaminedichloroplatinum II). The study is associated with efforts to understand and ameliorate the side-effects of chemotherapy, in particular nephrotoxicity. It is planned to provide for the first time a complete account of the retention and distribution of platinum in rats for a period of at least 2 months. Assay techniques used are graphite furnace atomic absorption spectrophotometry (AAS) and inductively-coupled plasma-source mass spectrometry. The latter offers high specificity and a sensitivity about two orders of magnitude greater than AAS; concentrations of less than 1 part per billion can readily be measured. Rats killed 1 week after administration retained 10% of the dose and at 2 weeks 7%. The highest concentrations were in the kidneys, followed by liver, bone and skin. Because of their substantial masses, the skeleton, skin and muscles contained the highest amounts of platinum, providing a reservoir for subsequent release and possible toxic effect. The *in vivo* X-ray fluorescent technique of Jonson, Mattson and Unsgaard (*Physics in Medicine and Biology, 33,* 847–857, 1988), using a source of polarized X rays, is being applied to measure platinum in the kidneys of patients shortly after cisplatin administration. Measurements are also being made of platinum concentration in plasma from patients, to study the effects of measures designed to protect the kidney on early dynamics and longer-term retention.

Reference

JONSON, R., MATTSON, S. & UNSGAARD, B., 1988. A method for *in vivo* analysis of platinum after chemotherapy with cisplatin. *Physics in Medicine and Biology, 33*, 847–857.

An audit of head and neck cancer treatment in a regional centre for radiotherapy and oncology

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A review has been made of all cases of head and neck cancer attending the regional centre during the 8-year period from 1 January 1980 to 31 December 1987. All 658 patients presenting with a new primary carcinoma, without evidence for metastasis outside the loco-regional area, who were treated primarily by radiotherapy have been included in this audit. Considering the patients treated with radical intent, there was a complete response rate of 95% in carcinoma of the lip, 67% in oral cavity, 74% in oropharynx, 47% in hypopharynx, 75% in nasopharynx and 95% in larynx. An analysis shows that T and N stage are the most important prognostic factors; those with T_1 and T_2 tumours showed a complete response rate of 90% compared with 59% for T_3 and T_4 tumours. The overall complete response rate for those without nodal involvement was 89% compared with 51% for those with secondary nodes at presentation. Of those who achieved complete regression, 28% relapsed either at the primary site or within nodes, but some were brought into remission by further management. Overall the results compare favourably with those reported by other institutions.

A 12-year survey of soft-tissue sarcoma of childhood

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Sixty children with soft-tissue sarcoma including one who developed a second sarcoma 12 years after radiotherapy for pelvic neuroblastoma were studied. There were 33 males and 27 females; six were under 1 year of age and the others were evenly distributed from 1 to 15 years. Sites of origin of the tumour extended from temporal region to foot and types of tumour were rhabdomyosarcoma (48), fibrosarcoma (9), liposarcoma (1), haemangiosarcoma (1), and leiomyosarcoma (1). Local bony erosions were seen in 13 (22%) of patients; 19 (32%) had metastases, including nine (15%) in the lungs. Other chest lesions were seen: 16 (27%) patients had attacks of pneumonia, three by opportunistic invaders. Haemorrhagic pulmonary oedema was noted at post-mortem examination in a girl with fibrosarcoma of pleura. Direct infiltration of pleura occurred in four patients and five had pleural effusions associated with pneumonia or metastases. Reversible cardiac failure and pulmonary oedema was encountered in one patient and progressive cardiomegaly occurred up to death in one boy with rhabdomyosarcoma because of drug toxicity. Rhabdomyosarcoma has a better prognosis than others. Twenty-four patients (40%) are alive and all are well except for two. Twelve were lost for follow-up. Of the 23 patients (38%) who died, 14 had rhabdomyosarcoma and nine had other types of sarcoma.

Magnetic resonance imaging of spinal marrow in the staging of patients with carcinoma of the breast

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Forty patients with carcinoma of the breast were studied with high-field magnetic resonance imaging (MRI). The results of MRI of the thoracic and lumbar spines were compared with those of conventional skeletal survey and radionuclide bone scan. Magnetic resonance images were obtained on a Siemens Magnetom unit operating at 1.5 T. Sagittal T_1-weighted images were obtained in all patients. Conventional staging with radionuclide scintigraphy and plain radiographs produced equivocal results in 20 patients. In this group, MRI demonstrated marrow abnormalities compatible with metastases in 50%. In patients with vertebral wedge collapse, MRI was particularly helpful in determining whether the cause was due to osteoporosis or metastatic disease. Twenty patients considered at high risk of bony metastatic disease clinically with negative results with conventional staging were also examined. In this group four out of 20 patients showed marrow abnormalities compatible with metastases. In selected patients, MRI may enable more accurate staging of patients with breast carcinoma by the demonstration of metastatic bone marrow disease.

Donkeywork: a data structure for small radiotherapy computing applications

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Many small radiotherapy computing applications require the programmer to perform a series of standard operations on small data sets, *i.e.* interpolating a TAR file or plotting a dose profile. Data sets are divided into two categories, "two dimensional (2D)" where $y = f(x)$ and "three dimensional (3D)" where $z = f(x,y)$. For example, an output factor is a function of field size and a TAR is a function of depth and field size. These data structures can be used both for the input of data to be used and for the display of results. Fortran 77 routines have been written to perform a number of frequently required tasks. The data structures may receive values from the keyboard, digitizer or user's application. They may be normalized or output to any commercially available spreadsheet program for sophisticated data manipulation. They may be stored on disk in a standard format and retrieved. Data may be merged by adding or subtracting entire data sets. Several 2D data files may be displayed as overlaid graphs for comparison purposes and 3D data may be displayed as a sequence of graphs, isodose contours or as a three-dimensional isometric surface. Specific features of the system include device independent graphics, self-scaling and self-annotating graphs, pull-down menus and robust data validity checks. The main advantage of this approach is the reduction in the number of similar routines that need to be written to perform standard tasks, such as the interpolation of data files. Another advantage is that it allows data sets to be examined in many different ways, thus highlighting erroneous values. The goal is to allow the user to deal with a set of data values with the ease of dealing with a single number.

The optimal dose for single-exposure radiotherapy of skin cancer

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Single-exposure radiotherapy has obvious advantages in the treatment of small superficial carcinoma of the skin. To define the optimum criteria for this form of treatment we have studied retrospectively 1005 cases of basal cell carcinoma (BCC) and squamous cell carcinoma (SCC) of the skin treated by a superficial X-ray machine (45 kV or 100 kV: FSD = 10 cm) in this institute in 1976. Three radiation doses were used: 22.5 Gy, 20 Gy and 18 Gy. The majority (94.1%) of the tumours were treated by a portal with a diameter of between 1.5 and 3 cm. The crude 10-year tumour control rate was 95.6% and late radiation necrosis rate was 6%. The optimal applied dose was 20 Gy for a lesion on a flat surface but 22.5 Gy was needed for a lesion at the inner canthus because of concavity of the treatment area. Within the range of treatment conditions described, the incidence of late skin necrosis was not affected by the quality of X rays or size of treatment portals. Radiation dose corresponding to 50% tumour control probability (TCD_{50}) was 13.89 ± 0.67 Gy.

Does surgery have a role in the management of small cell lung cancer?

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Intrathoracic relapse remains a major cause of failure and death in patients with small cell lung cancer (SCLC) treated by chemotherapy, even when thoracic irradiation is used. Surgical clearance of the tumour bed could possibly help reduce this problem, and so surgery has been integrated with chemotherapy and radiotherapy in an attempt to improve results. Fourteen patients with limited-stage SCLC have been treated by surgical resection, combination chemotherapy and thoracic irradiation. Nine of these had tumours considered operable at presentation, and underwent primary surgery followed by chemotherapy and consolidation radiotherapy to the tumour bed (in four of these, the histological diagnosis was not made until after resection). The other five patients were submitted to surgery when, after receiving six cycles of induction chemotherapy, their tumours were deemed operable or in complete remission; radiotherapy was given post-operatively. Median survival of these patients is 27 months; actuarial survival at 3 years is 48%. Recurrence within the chest has occurred in only one patient. This group of SCLC patients had fared extremely well and such patients are probably too few in number ever to be the subject of randomized studies comparing the aggressive approach reported here with other types of treatment. Small cell lung cancer patients should be offered surgery when feasible.

Peripheral doses from linear accelerators with universal wedges

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The peripheral dose (PD) is that delivered to tissues outside the collimated radiotherapy field. This dose becomes of clinical concern if it should approach the tolerance levels of the uninvolved tissues. It has been recognized that a wedge filter will elevate the PD. Some new linear accelerators employ an automated universal wedge mounted within the treatment head above the variable diaphragms. Because this wedge is at an extended distance from the patient and because any scattered radiations from it are heavily filtered by structures within the treatment head, the characteristics of the PD generated by a universal wedge will differ from those due to a wedge mounted in the more customary position below the treatment head. This paper presents the results of peripheral dose measurements in a water phantom and in air for two different linear accelerators equipped with universal wedges as a function of beam energy, field dimension, depth and wedge orientation. It is shown that the PD, relative to the central axis maximum dose, has a strong dependence upon wedge orientation, field dimension and off-beam distance, but has a limited dependence upon depth. The clinical relevancy of these measurements is also discussed.

The relationship between oedema of the arytenoid mucosa and radiation dose following the treatment of early cancer of the larynx

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Oedema of the mucosa overlying the arytenoid cartilages of the larynx is a consequence of radiotherapy for laryngeal cancer. This oedema is seen 6 weeks after completion of radiotherapy and in the majority of cases has disappeared after a further 3 months. The oedema may also occur as a result of lymphatic obstruction within the larynx. However, invasion of the lymphatic system of the larynx only rarely occurs in cases of cancer confined to true vocal cords (T1 N0 M0 glottic carcinoma). In these early cancers mucosal oedema can be considered because of radiotherapy. Between 1 August 1977 and 31 December 1984, 92 T1 N0 M0 glottic carcinomas were treated by megavoltage radiotherapy using one of two regimes. The first 23 cases (Group 1) were treated via parallel opposed fields in a full immobilization shell. The mean radiation dose was 65.71 Gy given in 30 daily fractions (95% confidence limits 65.43–65.99). Because of difficulties expressed by some surgeons in assessing the larynx 6 weeks after completion of radiotherapy owing to the presence of post-radiation oedema, the second 69 cases (Group 2) were treated in identical fashion but the radiation dose was reduced. A mean dose of 62.68 Gy was given in 30 daily fractions (95% confidence limits 62.49–62.87). This dose reduction was therefore 4.6%. The incidence of post-radiation arytenoid oedema in Group 1 was 47.8% and in Group 2 21.7% ($p < 0.05$, χ^2 with Yates' correction). For Group 1 the recurrence rate was 8.7% and for Group 2 10.1%. This difference is not significant. In conclusion, a dose reduction of the order of 5% is clinically detectable and at the levels used in early cancer of the larynx was not associated with a reduced cure rate.

Anal canal carcinoma: radiation therapy and chemotherapy versus surgery

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Seventy-eight patients with anal canal carcinoma were treated between 1970 and 1988. Two treatment groups were analysed.

(1) Forty-eight patients were treated by surgery alone. The median age of the patients was 63 years (range 35 to 79 years). The TNM (1987) stages were: T1 (1), T2 (24), T3 (12), T4 (8), N0 (27), N1 (13), N2 (2), N3 (2). Typing and grading were: squamous carcinoma (38), basaloid carcinoma (10), G1 (12), G2 (23), G3 (10) (unknown 3). Therapy consisted of APR in 44 out of 48 and LE in four out of 48 patients. Forty-two out of 48 were treated with curative intent (R0). After a median follow-up of 8.5 years, 23 out of 48 are alive and 20 out of 23 are disease free; 25 out of 48 died (post-operatively (3), recurrent disease (5), intercurrently (2), unknown (15)). The overall recurrence rate is 16.7% (8/48) and the 5-year survival rate is 51%. (2) Thirty patients received combined chemo–radiotherapy. The primary tumour region including inguinal and pelvic nodes was treated with AP/PA fields (6–10 MV, single fraction of 1.8–2 Gy, total dose 42–50 Gy, ^{192}Ir implant with 12–15 Gy in seven patients). Two courses of chemotherapy consisting of 5-fluorouracil (800–1000 mg/m^2 Days 1–4, 29–32) and mitomycin-C (10 mg/m^2 Days 1 and 29) were administered. Seven patients were excluded (primary metastatic disease (3), perianal cancer (1), intercurrent death (1), follow-up less than 2 months (2)). Nineteen patients were treated for primary disease, four for disease recurring after LE. The median age of the patients was 59 years (range 26–73 years). The TNM (1987) stages were: T1 (2), T2 (11), T3 (8), T4 (1), N0 (21), N1 (2). Histological typing showed 16 squamous and seven cloacogenic carcinomas. Six weeks after completion of treatment, 17 out of 19 had a clinically complete remission and two out of 19 a partial remission (salvaged by APR). Eighteen out of 19 are alive with NED, 15 out of 19 are colostomy-free and one patient died of intercurrent sepsis (median follow-up 15 months). Two out of four patients treated for recurrent disease achieved complete remission, two out of four had partial remission and died of progressive systemic disease. Acute morbidity consisted of mild to moderate diarrhoea and a myelodepression grade 3–4 (WHO) was observed in five out of 30 patients. Late complications were mild proctitis (after ^{192}Ir implantation) (1), sphincter sclerosis (after multiple LEs) (1), recto-vaginal fistula (50 Gy external beam, 15 Gy implant) (1). From these data we conclude that a combined regimen of chemo–radiotherapy is the treatment of choice for anal canal carcinoma.

The value of computed tomography in Stage 1 carcinoma of the cervix

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At this institute, patients referred with clinical Stage 1 carcinoma of the cervix are assessed prior to treatment by examination under anaesthesia. Treatment for Stages 1a, 1b and non-bulky Stage 2a is by intracavitary treatment (radium or Selectron) alone. Other stages and bulky Stages 1b and 2a also receive external-beam irradiation. A prospective study was initiated to evaluate staging computed tomography (CT) in Stage 1 carcinoma of the cervix; 49 patients presenting to this institute between 1980 and 1982 were entered into the study. Follow-up is available for a minimum of 5 years on all these patients. In addition to the routine assessment by biopsy (from the referring hospital) and examination under anaesthesia, this group of patients underwent CT. They were scanned on an EMI 7070 whole-body scanner, with a 3 s scan time, from 2 cm beneath the symphysis pubis to the iliac crests in contiguous 1 cm slices, and to the level of the renal hila at 2 cm intervals. Oral, intravenous and bladder contrast medium was given and a rectal catheter and vaginal tampon inserted. The results presented aim to assess the role of CT in this group of patients. This includes the correlation between the clinical and CT scan staging and the calculated predictive value of the scan. The implications of parametrial thickening as the solitary abnormality on the staging scan are also addressed.

Cisplatin-induced reduction in porcine renal reserve following unilateral nephrectomy

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Cisplatin (c-DDP)-induced nephrotoxicity is generally regarded as an acute reversible reduction in renal function occurring within days of treatment. Recently it has been suggested that c-DDP may also cause chronic irreversible reductions in renal function. Experiments were designed to determine whether prior administration of c-DDP reduced the compensatory increase in renal haemodynamics following unilateral nephrectomy (UN). Thirteen mature, 10-month-old, female Large White pigs received single doses of 1.5, 2.0 or 2.5 mg/kg c-DDP (n = 4, 6 and 3, respectively) infused intravenously. Glomerular filtration rate (GFR) and effective renal plasma flow (ERPF) were measured before, and 4 weeks after c-DDP administration. The left kidney of each c-DDP treated animal, plus that of four age-matched control pigs was then removed and GFR and ERPF measured in the remaining kidney every 4 weeks for up to 24 weeks after UN. Renal tissue from each kidney was processed for histological investigation. Although an increased c-DDP dose was associated with a higher frequency of reduction in GRF 4 weeks after treatment, the degree of this reduction varied markedly between each animal; no dose–effect relationship was apparent. Histologically there were dilated and/or atrophic tubules, with focal glomerular lesions. Following UN all kidneys exhibited a compensatory increase in renal function. However, this increase was dose-dependently reduced in the c-DDP treated pigs. Thus, the increase in renal function in pigs initially treated with 2.5 mg/kg c-DDP was <50% of that seen in age-matched UN controls. Moreover the glomerular damage was striking, ranging from varying degrees of glomerular sclerosis to obsolescent glomeruli. Thus, despite the lack of acute dose-related decreases in renal function, subsequent UN revealed a chronic dose-dependent reduction in renal reserve in c-DDP treated animals.

The Picker Synerplan treatment planning system: the first 3 years

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The facilitiies of the Picker Synerplan treatment planning system are reviewed and its usage at Newcastle General Hospital is discussed. The external photon beam algorithm has been commissioned for clinical use, including the beam blocking and irregular field facilities. Both bulk and pixel by pixel inhomogeneity corrections from CT are available. Work has started on the commissioning of the electron algorithm and first impressions are given. The brachytherapy point source algorithm has been used to calculate dose distributions around ^{125}I seeds and ^{137}Cs Selectron sources, and the line source algorithm has been used in the initial planning stages of ^{192}Ir breast implants. The conclusion draws together some of the pros and cons of the system from a user's point of view.

Percutaneous nephrostomy: its value in obstructive uropathy complicating uterine cervical malignancy

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Obstructive uropathy in uterine cervical malignancy may result from primary disease, recurrence or a treatment-related complication. Without intervention, early death inevitably ensues. Urinary diversion by surgical nephrostomy, cutaneous ureterostomies or a conduit carries significant morbidity and has often been avoided. The efficacy, simplicity, rapidity and low morbidity of percutaneous nephrostomy makes necessary reassessment of a more aggressive approach to management of renal failure. We have retrospectively reviewed all patients with uterine cervical malignancy and obstructive uropathy managed by percutaneous nephrostomy between November 1982 and December 1987 inclusive. In eight patients, renal failure was present at the time of diagnosis. Six were subsequently treated with radical irradiation. Two are alive and well at 278 and 321 days, two died of their disease at 331 and 503 days, one is alive with disease at 449 days and the sixth survived less than 3 months. Recurrence was the cause of the obstructive uropathy in 10 patients; median survival post nephrostomy in this group was only 74 days. In the remaining seven patients, ureteric obstruction was related to previous irradiation: all are alive and disease free, median survival being 390 days. The procedure was well tolerated. The effect of age of the patient, haemoglobin level, renal function and site of obstruction on outcome are discussed. We conclude percutaneous nephrostomy is of value in untreated patients and in those with treatment-related complications. Its role in patients with recurrent disease is less clear, median survival in this group being less than 3 months.

A dose-optimizing algorithm for multiple-beam conformal radiotherapy based on the technique of simulated annealing

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The aim of conformal radiotherapy, to tailor the high-dose region to the tumour with maximal sparing of damage to normal and particularly radiosensitive anatomy, makes great demands on "conventional" treatment-planning methodology, whereby an experienced operator varies beam positions and weights until an acceptable dose distribution is determined. Instead, computational optimization is required in view of the potentially large number of beams which might combine for each treatment fraction. An optimization method known as simulated annealing has been developed and is described in this paper. The user specifies the tumour volume (to be raised to a nominal "100% dose") and also the sensitive regions to be kept below some prescribed "harmless" (say 15%) dose together with the dose which other normal structure may receive. For a pre-set number of beams (up to 128) the algorithm then computes the optimal distribution of elemental beam weights along each beam in the sense of most closely fitting the dose prescription. Results are shown for a horsehoe-shaped tumour enclosing a sensitive region wherein the latter is successfully shielded whilst the high-dose region is carefully tailored to the tumour. The χ-squared fit over the whole slice (defined as the rms difference between the required and delivered dose) is better than 20%. Preliminary results have been obtained with a simple beam model and mathematical dose distributions in single slices. These restrictions will be lifted as the method is refined. Computations have been performed on a VAX 750 computer. The technique is closely analogous to similar methods published by the author for optimal reconstruction of emission tomograms from SPECT data. The problems are "mirrors" for each other in that in the imaging analogy, the data in the slice are adjusted to fit optimally the projections.

Use of a three-dimensional ultrasonic digitizer for the acquisition of surface outlines in radiotherapy treatment planning

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A prerequisite for radiotherapy treatment planning is an accurate patient contour in the plane of beam incidence. Ideally, dosimetry models should take account of the size, position and physical properties of heterogeneities within the patient. Computed tomography can provide these as well as surface contour data. It is, however, expensive and not always readily available. It may also be difficult to reproduce the patient's treatment position on a CT scanner. Most current contouring devices tend to be cumbersome in use and not readily angled to the required plane. A patient contouring device has been developed using a three-dimensional ultrasonic digitizer. This device is used for industrial computer-aided design. Data can be acquired within an active volume up to a 2 m cube. This provides ample accommodation for patients and patient casts. The system is mobile and can be used in the treatment room, simulator or planning room. The time necessary to position the device in relation to the patient is minimal and, because the system is three-dimensional, contours may be taken in any plane required. Acquisition of data is rapid and printed copies of the outlines, stored in digital form, are readily obtained. Transfer of outline data directly to a treatment planning computer is the ultimate goal. Extensive tests have been conducted to assess the accuracy and reproducibility of the system. Both raw data and processed data, presented in the form of the outline, have been assessed. Two algorithms for the transformation of data into the required plane have been developed. The raw data has been examined for variations in probe orientation and speed of movement throughout the active volume. It has also been examined under varying ambient conditions. The processed data has been assessed for known phantom shapes and patients' casts.

The importance of ultrasound in the diagnosis of recurrences after radiotherapy of soft-tissue sarcomas

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In the period October 1987 to October 1988, 71 ultrasound examinations of treated regions were carried out on 38 patients who had been irradiated to treat soft-tissue sarcomas. In eight cases, the findings suggested a recurrence. Weakly echoing, generally spherical, clearly defined structures were characteristic findings. Five findings were confirmed by histology, two others were scar tissue, and one was not investigated further as clearer findings would not influence the therapeutic measures. Five of the above eight structures were palpable and four were discernible on CT scans. The results underline the importance of ultrasound as a sensitive diagnostic method for follow-up examinations after treatment of soft-tissue sarcomas and suggest it should be used routinely.

Can computed tomography differentiate large residual sterilized masses from recurrent tumour?

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Serial computed tomography (CT) images from eight patients with residual masses following chemotherapy for malignant disease were reviewed. Testicular teratoma was the primary diagnosis in four patients, non-Hodgkin's lymphoma in three, and Hodgkin's lymphoma in one. Six patients underwent surgical biopsy of residual masses after chemotherapy. One patient demonstrated tumour recurrence, whilst five patients were found to have sterilized masses. Surgery was not carried out in the remaining two patients, but serial CT over a 1-year period showed a decrease in the size of residual masses in conjunction with normal clinical and biochemical findings and these were thought to represent sterilized tissue. Abnormal lymph node masses on pre- and post-chemotherapy CT scans were analysed in all patients with regard to size, morphology and the presence of necrosis or calcification. Three patients showed an increase in size of these masses following chemotherapy, as opposed to five patients who showed a decrease. Calcification and necrosis were observed in one and three patients pre-chemotherapy and in two and four patients post-chemotherapy, respectively. The single patient with tumour recurrence showed an increase in size in tumour mass with marked necrosis and calcification on CT. Our findings suggest that CT is an insensitive method of differentiating sterilized residual masses from recurrent tumour and we conclude that surgical biopsy should be carried out where doubt exists.

Breast recurrence in young patients treated conservatively for breast cancer

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Between 1979 and 1986, 263 patients in a predominantly young age group (median 42 years, range 23–69 years) were treated conservatively for breast cancer. This breast-conserving treatment (BCT) consists of macroscopic tumour excision followed by whole breast irradiation (45 Gy in 4½ weeks using a 6 MV linear accelerator, no bolus) with a 15 Gy "boost" (eight fractions, various techniques) to the tumour bed. Breast recurrence has occurred in 56 patients and has progressed to uncontrollable ulceration in 18. Overall survival has been comparable to that of patients treated by mastectomy. As in other reported series, the risk of breast recurrence was higher in younger patients (comparing patients less than 40 years with those over 40 years, log rank statistic = 9.99, $p < 0.01$). Other highly significant risk factors were histological evidence of vascular invasion ($p < 0.001$) and tumour size greater than 2 cm ($p < 0.001$), which were found more commonly in younger patients. For that group of patients with neither vascular invasion nor tumour size greater than 2 cm, the younger ones (<40 years) had no higher risk of breast recurrence than the older (>40 years) ones. There were 116 patients whose tumours showed neither of these two bad prognostic factors, in only one of whom did uncontrollable local recurrence occur. Vascular invasion and large tumour size are the most sinister factors for breast recurrence after BCT. Younger women whose tumours have neither of these factors are at no greater risk of recurrence than older ones.

In vivo ^{19}F nuclear magnetic resonance spectroscopy: human 5-fluorouracil pharmacokinetic comparison of intraperitoneal versus intravenous drug administration

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5-fluorouracil (5-FU) is commonly employed in the treatment of advanced colorectal carcinoma and is also used as an adjuvant following attempted "curative" surgery. Unfortunately, response rates are only of the order of 25% in advanced disease and equivocal results have been obtained when used in the adjuvant setting. Transperitoneal drug absorption is primarily into the portal system draining directly to the liver, which is the commonest site of metastatic disease. 5-FU is cell-cycle and phase specific, therefore cytotoxicity is related to the duration of exposure. Clinical data suggests that intraperitoneal (i.p.) administration of 5-FU may be more effective than administration by intravenous (i.v.) bolus injection. Comparison of hepatic 5-FU pharmacokinetics administered at a dose of 1 g by i.v. and i.p. routes has been undertaken in a number of adult patients, using a 1.5 T field whole-body NMR spectrometer employing FID sequences and the FROGS localization technique. 5-FU and the major hepatic metabolite fluoro-beta-alanine (FBAL) were detected in all subjects. Measurements were continued until disappearance of the 5-FU peak. Hepatic pharmacokinetics following i.v. administration were similar for the subjects measured. With intraperitoneal administration there was considerable variation. Such inconsistency may result from uneven drug dispersion throughout the peritoneum, inflammatory changes, disease or variation in portal blood flow. The pharmacokinetics of hepatic accumulation of FBAL were more consistent, whether 5-FU was given i.v. or i.p. In conclusion, *in vivo* ^{19}F NMR spectroscopy is a variable non-invasive technique for the investigation of cellular metabolism of 5-FU.

Radiology and Psychology: The Final Frontier

Chairman: Dr A. G. Gale

Computer-assisted perception of radiographs
C. Nodine, H. L. Kundel, E. A. Krupinski and L. C. Toto
Advanced artificial intelligence methods with applications to radiographic interpretation
I. Moorhead
Aptitude and training in radiology
G. E. Walker
Human factor aspects of reading radiographs
M. Sinclair
Applying pyschological models in radiology
A. G. Gale

Computer-assisted perception of radiographs

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This paper discusses the feasibility of using computer-assisted visual feedback to improve the perception of medical images. Diagnostic interpretation in radiology is prone to error. These errors are due primarily to the fact that the perceptual system evolved to perceive real-world objects, not images of them. Image perception is based on the perceptual system's inherent ability to extract the pictorial counterparts of visual-world perceptual invariants from images. Unlike visual-world perceptions, image perceptions are constructed out of the dialectic interaction between perceptual experience and cognitive inference. They are plausible perceptual interpretations of the limited visual-world data provided by the image, and as such are thus subject to illusion and error in the same sense as visual-world perception. Because of their unique status, according to this view, image perception cannot absolutely resolve questions of truth in the same way as can visual-world perception. This creates problems for diagnostic radiology as well as other visual sciences that are concerned with extracting truth from images. We have been working on ways of helping the perceptual system remedy this problem. Briefly, our strategy is to help the radiologist recognize missed lung nodules by (a) measuring eye fixations during an initial examination of the chest image, (b) analysing, by computer, regions of the image that receive long-dwell fixations when the radiologist's decision is negative and (c) playing back the computer-identified long-dwell regions for re-evaluation. We present research that shows that regional dwell is a reliable predictor of missed nodules, and report preliminary results of a study designed to test the effectiveness of computer-assisted visual feedback in improving the accuracy of perceiving lung nodules in chest radiographic images.

Advanced artificial intelligence methods with applications to radiographic interpretation

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There is currently a resurgence of interest in developing computer vision systems that are not fixed and inflexible, but are able to modify their operation according to experience. These devices are based on how real neural systems operate and are variously referred to as neural nets, connectionist models or neural computers. They attempt to capture some of the characteristics of animal and human sensory systems, in particular, the ability to learn, to generalize and to degrade gracefully, either when damaged or as the quality of the sensory data reduces, for example, as a result of noise. In addition, they do not require explicit rules for their operation and therefore avoid the difficulties of knowledge elicitation that arise with current artificial intelligence techniques. In this paper I describe a particular type of neural net (a back propagation learning network) that acts as a sophisticated classifier. It can learn arbitrary input–output mappings simply by being presented with examples of the types of inputs and outputs required. The operation of this type of net is illustrated with examples of feature extraction from images. The images that were used were generated synthetically and were then pre-filtered in a way that corresponds to the early stages of the human visual system. The networks were trained with these pre-filtered images. The behaviour of these trained networks when applied to various types of image is presented and their application to radiographic interpretation discussed.

Aptitude and training in radiology

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This paper considers the application of psychology to the related areas of training and aptitude for diagnostic radiology, taking mammography as its model. Until relatively recently, training in reading radiographs has been somewhat idiosyncratic despite some efforts to pursue a more systematic approach. However, the commencement of national breast screening has focused attention on the need to adopt more standardized training procedures in order to both quickly attain and maintain high levels of quality. A programmed learning approach is described which concentrates on radiological feature detection. This essentially "bottom up" approach to training in pattern recognition, where one looks for perceptual cues and attempts to build up a series of correct schemata in memory has been found useful, particularly as a starting point for training novice observers. This method also raises an intriguing question: when it is applied to similarly qualified observers then different radiograph reading performances are obtained. Is this because they respond differently to this particular training method, or do they have different aptitudes? The question of aptitude for mammography is pertinent as screening becomes more widespread. Can psychology provide a means for identifying those individuals with particular aptitude for screening at an early stage of training? Standardized perceptual and cognitive tests have been administered to various populations and results correlated with their radiograph reading performance. Such tests can also help

elaborate at which stage in the radiological reporting process particular errors occur. It is argued our results demonstrate that investigations of learning techniques, training programmes and personnel selection can be assisted by a psychological approach.

Human factor aspects of reading radiographs

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This paper discusses briefly some of the human factor variables that affect the quality of data obtained from radiographs. These are then grouped into classes to indicate their accessibility for control (easy to control, difficult to control, out of control) to improve the quality of data obtained. Methods of controlling these variables are briefly outlined, and a very brief discussion is given of some of the implications for management.

Applying psychological models in radiology

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Diagnostic radiology entails the efficient interpretation of pertinent information present in medical images. This task involves various complex perceptual and cognitive processes. It is impossible to visually attend simultaneously to all the information displayed in the image and so the radiologist must first search for and then detect salient features. This leads on to the recognition and finally the appropriate interpretation of the abstracted information. It is argued that this interface between the observer and the medical image can be adequately described using psychological models which take into account recent developments in visual attention theory. The importance of modelling the radiological task is that it allows predictions to be made of what will happen when task parameters alter and the adequacy of a particular model can be ascertained by how well such predictions are borne out in practice. Various illustrations of the usefulness of this approach are described from different areas of radiology. The increasing use of technology in the presentation of digital and multiple format images to radiologists serves to highlight the importance of the adequate understanding of this interface, both in the design of image presentation devices, and in the full appreciation of the complexities of radiological diagnosis.

Teach-in: Pitfalls in Computed Tomography of the Chest

Chairman: Dr S. J. Golding

Pitfalls in computed tomography of the chest

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The effective use of CT in the chest, as in other areas of radiology, requires knowledge of the clinical problem, limitations of the technique, the normal anatomical appearances and the variations that may simulate disease. Expectations of CT have grown in parallel with its technical advance. To ensure that these expectations are met, clinico-radiological discussion is necessary to define accurately the clinical requirements. Discussion may alter the number and position of sections performed, the way in which the data are processed and may indicate a procedure other than CT as the optimum approach. Examination of the thorax places unique demands on the instrument and its operator. Involuntary movement, the dual blood supply of the lungs, the high resolution required to image peripheral blood vessels and the wide variation in tissues can all result in misinterpretation. The effects vary according to the performance of individual scanners and the radiologist needs to be aware of the characteristics of his or her own machine. Diagnosis depends heavily on defining the anatomical site of the lesion. The mediastinum represents the area of greatest anatomical complexity and variation. This is particularly true of the vessels and the radiologist must be aware of not only the anatomical variance but of the appropriate use of enhancement techniques. Enhancement is an essential component of the examination when distinguishing between vessels and masses or in the diagnosis of disease of the vessels themselves. In the rest of the chest, awareness of the anatomy is usually sufficient to prevent misinterpretation. Pathology may, however, so distort normal structures that accurate diagnosis may be difficult, particularly if the lesion is large or closely related to the diaphragm. The role of the radiologist has expanded and now includes biopsy and intervention in the thorax. The role of CT in these areas is limited, other than as a guide for biopsy procedures. Potential problems include the selection of biopsy needles and the planning of biopsy routes.

Nuclear Medicine

Chairmen: Drs R. J. Burwood and A. J. Coakley

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Perspectives in tumour imaging

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Historically radionuclide techniques for imaging tumours date back to the 1950s with the use of ^{131}I to image sites of recurrent or metastatic carcinoma of the thyroid. Over the past three decades much time and money has been expended on attempts to develop sensitive and specific tumour imaging agents that will permit the diagnosis and localization of primary and metastatic disease and facilitate accurate staging and assessment of tumour response to therapy. Unlike other imaging techniques, radionuclide imaging of tumour, if successful, carries with it the further possibility of labelling the tracer radiopharmaceutical with therapeutic doses of radionuclide thus targeting the therapy dose to the tumour. Radionuclide techniques for tumour imaging may be divided into (i) the non-specific techniques of general use such as ^{99}Tc^{m} diphosphonate bone imaging for highly sensitive detection of skeletal metastases, (ii) specific tumour imaging techniques of general use such as ^{67}Ga citrate for imaging lyphomas and (iii) the rapidly increasing numbers of specific tumour imaging agents of limited use such as ^{123}I and ^{131}I metaiodobenzyl guanidine (MIBG) for imaging neuroectodermally derived tumours, and (iv) radiolabelled antibodies to tumour associated antigens. ^{123}I and ^{131}I MIBG, developed in Ann Arbor, Michigan, USA, is now routinely used in diagnostic imaging for phaeochromocytomas and neuroblastomas and has some limited use in other neural crest tumours such as carcinoid tumours, paragangliomas and medullary carcinomas of the thyroid. The significant uptake of ^{131}I MIBG has encouraged the use of this agent in therapeutic doses with good initial results reported. Radiolabelled antibodies to tumour associated antigens are also being widely investigated at the present time. Non-specific uptake in liver and bone marrow has meant that this technique has lacked sensitivity particularly in the detection of abdominal lesions. However, encouraging results have recently been obtained with anti-melanoma antibodies and new ^{99}Tc^{m} labelled antibodies appear promising. This paper reviews the current place of radiopharmaceuticals in the detection of primary and secondary tumours and identifies promising research areas for the future.

The gastrointestinal tract: where are we now?

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The number of studies of the gastrointestinal tract which are undertaken in nuclear medicine departments varies considerably. Generally this is due to unfamiliarity with the tests, or uncertainty as to when they are of value. Gastric emptying is historically interesting and is useful in sorting out the problems of patients after peptic ulcer surgery, or in examining situations where emptying is delayed or hastened. Attention to technique is important. The use of dimethyl iminodiacetic acid (HIDA) derivatives has allowed the saga of bile reflux to be unravelled. Reflux may be normal, but it is important to establish its presence before corrective surgery for reflux is undertaken. Detection and correction of oesophageal reflux is paramount, and its presence is related to the length of Roux-en-Y loops. Dimethyl iminodiacetic acid derivatives are used extensively in North America to diagnose acute cholecystitis. Because of surgical practice the tests are rarely used in the UK. Jaundice is generally resolved using ultrasound. However, HIDA is useful in some conditions, notably biliary atresia. Assessing the extent and severity of inflammatory bowel disease, especially Crohn's disease, can be difficult and barium studies are not always reliable. Many clinicians do not appreciate the value of labelled white blood cell studies, and 4-h images are generally optimal. Finally with gastrointestinal bleed the site of the bleed is usually found on endoscopy. There is however a minority of patients who prove difficult. A straightforward test for Meckel's diverticulum is available but not always easy to report. Controversy exists about detecting other causes of bleeding, but merely arranging the test seems to stop further bleeding. However, results are helpful but sometimes localizing the precise site of the bleeding recalls the title of this paper: "Where are we now?".

Impaired left lower lobe ventilation: an isotope study of mechanisms

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A retrospective review of 90 elderly patients undergoing V/Q scans showed a significant correlation between cardiac enlargement and reduced left lower lobe ventilation ($p < 0.001$). A prospective study on 19 patients showed a marked improvement in left lower lobe ventilation in the prone compared with the supine position in patients with large hearts. Although there was a similar change in normal volunteers this was less marked. In order to elucidate the mechanism of this change, 11 patients were given intravenous ^{133}Xe to study regional lung perfusion and ventilatory turnover, inhaled ^{81m}Kr to study regional ventilation and intravenous ^{99}Tc^{m}-MAA to study regional lung perfusion. The results suggest that the reduction in ventilation in the left lower lobe in patients with large hearts is due to lung compression and alveolar closure without air trapping, and that a change in position reverses this closure and thereby improves lung ventilation and gas exchange.

Quantitative ^{67}Ga scintigraphy in the evaluation of pulmonary and peripheral sarcoidosis

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Gallium scintigraphy provides a sensitive indicator of disease activity in sarcoidosis, but relies on subjective analysis of the images. Computer analysis of regions of interest was used to quantify the image and establish a ^{67}Ga index. This was defined as the ratio of counts per pixel for the lung parenchyma or hilar region versus background (determined from the thigh). In addition, ratios were obtained for the lacrimal glands, nasal mucosa, parotid region, liver and spleen. Seventy patients with sarcoidosis and 19 controls were scanned 72 h following intravenous injection of 75 mBq of ^{67}Ga citrate, and the ^{67}Ga index was estimated for each area. In the control group the ratios fell within a fairly narrow range (see table). In patients with sarcoidosis the variation was much greater in each area except the liver, reflecting a wide distribution of disease activity. A significant difference between patients with sarcoidosis and controls was found in the hilar and parotid regions but not in the other areas studied.

	^{67}Ga index (mean ± SD)	
	Sarcoidosis ($n = 70$)	Controls ($n = 19$)
Hilum	4.8 ± 2.3	3.5 ± 0.9 ($p < 0.025$)
Parotid	2.9 ± 1.5	2.1 ± 0.7 ($p < 0.05$)

The ^{67}Ga index has proved a useful tool in the monitoring of patients with sarcoidosis and is now in routine use at our hospital.

New insights into the "superscan" of malignancy

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The classical appearance of a "superscan" on bone scintigraphy has been defined as a generalized increase in bone uptake of technetium-labelled MDP with a high bone to background signal ratio and reduced or absent renal visualization. These appearances occur most commonly in diffuse metastastic bone disease, particularly with prostatic carcinoma, but are also associated with other malignancies and metabolic bone disease, particularly hyperparathyroidism and osteomalacia. All bone scintigrams performed by the Nuclear Medicine department at Southampton General Hospital over the past 4 years and reported as showing the appearance of a "superscan" have been reviewed. From a total of over 50 patients, ~70% had prostatic cancer and 10% breast cancer. Several other malignancies were represented by smaller numbers, including lung cancer, bladder cancer, lymphoma and systemic mastocytosis. There were no "superscans" reported in connection with metabolic bone disease over this period. Several factors have been studied in depth to try and establish a correlation between the "superscan" and age at initial presentation, histological differentiation of the tumour, the presence of non-osseous metastases, the response to treatment and the patient's subsequent prognosis.

^{99}Tc^{m} red blood cell scintigraphy for unexplained gastrointestinal blood loss: an alternative to angiography in a district general hospital

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Identification of the source of acute or chronic gastrointestinal blood loss is vital if correct management is to be instituted. Although selective visceral angiography remains the gold standard, it requires an experienced interventional radiologist, full screening facilities and a patient who is actively bleeding at the time. These are not always available. Although ^{99}Tc^{m}-labelled red blood cell (RBC) scintigraphy requires nuclear medicine facilities, it is a simple technique, useful in both intermittent and active bleeding and within the capabilities of trained radiographers. Over a 5-year period at a district general hospital without facilities for urgent visceral angiography, ^{99}Tc^{m}-labelled RBC scintigraphy was used to investigate 22 patients (11 male, 11 female; mean age 67 years) presenting with active bleeding per rectum. Eighteen (81.8%) patients developed positive scans of whom one was referred for confirmatory angiography. Scans became positive as early as 2 min and up to 20 h following injection; most ($n = 13$) became positive within 30 min. The clinical circumstances of seven (31.8%) patients did not necessitate surgery but in 10 out of 11 who underwent surgery, the site of bleeding was identified. ^{99}Tc^{m}-labelled RBC scintigraphy was less successful in two other groups of patients studied. Scintigraphy was positive in only one out of four patients with a history of acute gastrointestinal haemorrhage but who were not clinically bleeding during the period of scanning. Scintigraphy was negative in 10 out of 11 patients (five male, six female; mean age 58 years) with chronic anaemia, confirming previous reports that it has little role in this group of patients. This study confirms that scintigraphy can play a vital role in the pre-operative localization of unexplained gastrointestinal bleeding. Since only two out of 37 patients studied were referred for angiography this study also supports previous work suggesting that scintigraphy should be performed prior to angiography.

Preliminary experience with technetium-99m labelled antifibrin T2G1s FAB′ monoclonal antibody in patients with deep venous thrombosis

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Radiolabelled specific monoclonal antibodies to fibrin have been developed that provide "hot spot" images of vascular thrombus. This technique may overcome some of the limitations associated with other methods used in confirming deep venous thrombosis. Early studies with indium 111 showed excellent clot avidity but this radionuclide has several disadvantages. We report our first experience with technetium-99m labelled antifibrin in the detection of deep venous thrombosis in humans. As a radionuclide, technetium 99m is more readily available and gives a lower radiation dose. Three patients were studied with venographically documented disease. Within 45 min of injection of the antifibrin monoclonal antibody, "hot spot" activity could be discerned in the region of the thrombus in two patients and became more intense over the next 5–6 h. In another patient who had undergone a total knee replacement and sustained a small peroneal venous thrombosis, intense activity around the prosthesis was noted at 30 min and 3 h but no convincing "hot spot" could be visualized in the region of the peroneal veins. No adverse reactions were noted in any of the patients studied. This technique clearly shows promise and further studies are warranted.

Development of renal scars after acute nephronia in childhood: a study of sequential DMSA scans

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The DMSA scan is the most sensitive imaging method for the detection of renal parenchymal damage after acute urinary tract infection in children under the age of 5 years (Verber et al, 1988). It is not known how often acute DMSA defects are reversible, nor the factors which determine progression to permanent scarring. In this study we have performed DMSA scans in a selected group of 45 children within 6 weeks of a first urinary tract infection and detected cortical defects in 49 kidneys. Follow-up scans have been performed 6 months or more after the initial presentation. In 40 (80%) kidneys the acute defects persisted and here in nine (20%) kidneys the scans have returned to normal. We have looked at those factors which may be related to outcome. There was a correlation between deterioration of defects and breakthrough infection in the presence of Grade 3 reflux ($p < 0.02$). There was no correlation between the result of the second scan and age, sex, reflux or breakthrough infection in the absence of Grade 3 reflux. All kidneys with an initial relative DMSA uptake of <35% remained abnormal at follow-up. Of the 41 kidneys that were initially normal, only two developed defects at follow-up; this was in a 2-year-old child with bilateral Grade 3 reflux and breakthrough infections. There were 12 kidneys that were persistently abnormal following acute nephronia in the absence of reflux; these children with significant renal disease would have been undetectable prior to DMSA scintigraphy. The DMSA scan is a unique clinical tool with which to study the genesis of chronic pyelonephritis.

Reference

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Scintigraphic demonstration of hernias associated with continuous ambulatory peritoneal dialysis

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Continuous ambulatory peritoneal dialysis (CAPD) is an increasingly popular treatment option in chronic renal failure, particularly in elderly patients. Abdominal hernias are well recognized complications of CAPD, with a prevalence of around 15% in several series. Most of these hernias are not clinically apparent prior to the commencement of CAPD, the increased intra-abdominal pressure being an important contributory cause. We have recently encountered three patients on CAPD with inguinal hernias. Because of the considerable oedema due to leakage of dialysis fluid associated with these hernias, it is often difficult or impossible to lateralize the side of the hernial sac, necessitating bilateral inguinal exploration. We describe a method of lateralizing the sides of origin of hernias by the simple procedure of adding technetium 99m-labelled DTPA to the dialysis fluid, and imaging over the groin area with the patient in the erect position. Representative images are demonstrated. Although this method has been previously described in the nephrology literature, it warrants wider recognition in view of the increasing number of patients undergoing CAPD.

Chest: proffered papers and posters

Chairman: Dr S. J. Golding

Linear opacities as a feature of pneumocystis pneumonia
J. E. Page and A. G. Wilson
Unusual presentation of *Pneumocystis carinii* pneumonia in five patients with the acquired immune deficiency syndrome
M. McCarty, R. W. Kerslake, D. Robinson and A. H. Choudhri
Legionnaires' disease: the radiographic findings of the London epidemic
J. J. Donald, J. A. D. Annis and D. S. Grant
Magnetic resonance imaging in the management of cystic fibrosis
D. C. Kinsella, P. Goddard, A. Duncan, A. Hamilton and F. Carswell
The morphological spectrum of pulmonary arterio-venous malformations: radiological features and mimics
G. McGann, D. M. Hansell and C. R. Murch
The value of computed tomography in the diagnosis of amiodarone-induced pulmonary toxicity
A. A. Nicholson and C. Hayward
Chest radiographs following permanent cardiac pacing: are they really necessary?
D. J. Grier, P. Cook and G. Hartnell
A review of the use of the pre-operative chest radiograph within a teaching hospital
H. J. Fairhurst and P. M. Taylor
Iotrolan in selective bronchography via the fibreoptic bronchoscope
S. K. Morcos, S. V. Baudoin, P. B. Anderson, R. W. Bury and R. Beedie
Role of transthoracic needle biopsy of lung masses following unsuccessful transbronchial biopsy
E. Breatnach and P. H. Nath
The value of chest radiography, computed tomography and radionuclide scanning in thoracoplasty/plombage patients: correlation with clinical and respiratory function
H. Lee, A. L. Hine, H. Thomson and M. W. McNicol
Computed tomography or chest radiography in the assessment of response to radiotherapy in lung cancer
E. Lyn, W. Ayoub, M. I. Saunders and S. Dische

Linear opacities as a feature of pneumocystis pneumonia

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Linear opacities are generally regarded as being an uncommon feature of pneumocystis pneumonia. The authors experience, however, suggests that this might not be so and that such linear opacities might have diagnostic value. A total of 22 episodes of pneumocystis pneumonia occurring in 20 patients between March 1987 and October 1988 were reviewed for evidence of linear opacities. These were present in nine out of 22 episodes (41%). In all cases the linear opacities were transient and related to the acute episode. They were always associated with other radiographic changes and never antedated these. Associated radiographic features included the more typical perihilar or mid/lower zone "ground glass" opacification, and less frequently, nodular shadowing or localized areas of consolidation were seen. The linear opacities were typically one to three in number, 1–2 mm thick (maximum 5 mm) and 1–3 cm in length (maximum 7 cm). They occurred predominantly in the mid and lower zones, more commonly on the right. Septal (Kerley B) lines were also seen in some cases. The significance of these findings is discussed. In this series, linear opacities occurred more frequently than previously reported and may be of diagnostic value.

Unusual presentation of *Pneumocystis carinii* pneumonia in five patients with the acquired immune deficiency syndrome

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Pneumocystis carinii is a common respiratory pathogen in the immunocompromized. Of 230 patients with the acquired immune deficiency syndrome (AIDS) seen at our hospital, 55% have had pneumocystis pneumonia on at least one occasion. The typical radiographic appearances of respiratory involvement have been well described. In the early stages, subtle perivascular cuffing is seen, which progresses to diffuse alveolar consolidation of the type seen in pulmonary oedema, usually sparing the apices and the lung peripheries. In severe cases, there is massive bilateral consolidation with air bronchograms. However, atypical radiographic appearances are being increasingly recognized. We have seen five AIDS patients with only upper lobe changes, and although tuberculous infection was suspected initially, *Pneumocystis carinii* was the only pathogen found on bronchoalveolar lavage and transbronchial biopsy. Moreover, these patients improved on therapy directed against pneumocystis alone. We present the radiographic appearances in these patients and compare them with features we have seen more commonly in pneumocystis infection. This series emphasizes the need for aggressive diagnostic methods in immunocompromized patients who have respiratory symptoms, as the likely pathogen cannot be predicted from the radiographic appearances.

Legionnaires' disease: the radiographic findings of the London epidemic

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The radiological findings of a recent epidemic of Legionnaires' disease centred around Broadcasting House, London, in April 1988 are presented. The chest radiographs of 12 male and five female patients (17 cases) with confirmed Legionnaires' disease are reviewed. The mean age of the group is 58 years with a range of 32–78 years. Films from the radiographic series of each patient were analysed at the beginning, at peak radiological severity, and at the end of the series. Five (29%) patients had normal chest radiographs initially and three of these remained normal throughout the illness. Eight (47%) patients demonstrated radiological evidence of unilateral lobar consolidation on their first examination. Other initial findings included poorly marginated, rounded opacities (one case), unilateral perihilar consolidation (two cases) and unilateral peripheral consolidation (one case). Twelve patients from the total series demonstrated radiological progression of disease, and of these, 42% developed bilateral pulmonary consolidation. Pleural effusion was present in six (35%) of all the cases. This study is unusual in that it represents the findings of a local epidemic rather than the previous cumulative reports of sporadic cases. The high incidence of normal radiographs is not typical and possible explanations for this are discussed.

Magnetic resonance imaging in the management of cystic fibrosis

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Eight children with cystic fibrosis underwent magnetic resonance imaging (MRI) of the chest and sinuses. The resulting images were compared with the patient's clinical condition and chest radiographic findings. The scans were performed on a Picker 0.5 T Vista 2055 scanner. The chest was imaged in the coronal plane with T_1-weighted and STIR pulse sequences. Respiratory gating was used. The images of the sinuses were in the axial plane and were T_1 weighted. Magnetic resonance imaging gave precise anatomical identification of hilar and mediastinal lymphadenopathy that was not apparent on the chest radiograph. The lymphadenopathy was due to chronic pulmonary infection. Hilar lymphadenopathy can be distinguished from pulmonary artery enlargement because of the signal void produced by flowing blood within the vessels, without contrast medium injection. Pulmonary parenchymal abnormalities are also clearly demonstrated. Both mucoid impacted bronchi and peri-bronchial inflammatory disease have characteristic appearances allowing distinction from pulmonary vessels. In comparison with the chest radiograph, the extent of parenchymal involvement is greater on the MRI scans. The sinuses in all cases showed severe generalized disease.

The morphological spectrum of pulmonary arterio-venous malformations: radiological features and mimics

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Material from 31 cases of pulmonary arterio-venous malformations (AVMs) seen at the Brompton and Westminster Hospitals over the last 30 years is presented. The radiological features of the commonest type of AVM are well known and in the clinical context of central cyanosis and a family history of haemorrhagic telangiectasia the diagnosis is straightforward. It is becoming increasingly recognized that there is a wide variation in the complexity, size and distribution of AVMs with a resulting broad spectrum of radiological appearances. Because of their relative rarity there has not yet been a comprehensive morphological classification of pulmonary AVMs. Pulmonary AVMs may be acquired rather than congenital and aetiologies include trauma, surgery and cirrhosis. The plain radiographic and arteriographic features of the AVMs occurring in these acquired conditions and unusual manifestations of congenital AVMs are illustrated. In addition, abnormal pulmonary vessels which can mimic pulmonary AVMs but which have no haemodynamic or clinical significance are discussed.

The value of computed tomography in the diagnosis of amiodarone-induced pulmonary toxicity

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Amiodarone hydrochloride (Cordarone) is an effective anti-arrhythmic drug with numerous side-effects. One of the most serious is a potentially fatal pneumonitis. The clinical diagnosis is difficult and plain radiography, respiratory function tests and histology are either non-specific or unhelpful. The value of CT in the diagnosis and follow-up of patients with other interstitial lung diseases is now established. We scanned nine patients who developed new respiratory symptoms while taking amiodarone. Four of the nine patients had peripheral, high-density, pleuro-parenchymal, linear opacities similar to those described previously in cryptogenic fibrosing alveolitis. One patient had a CT scan appearance compatible with early pulmonary oedema and one had an appearance suggesting bronchiolitis obliterans. Three scans were normal. We suggest that CT is a useful investigation in patients with suspected amiodarone pulmonary toxicity.

Chest radiographs following permanent cardiac pacing: are they really necessary?

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Permanent cardiac pacing is a commonly performed procedure (150 cases/million population) and chest radiographs are frequently requested following insertion and at follow-up clinics. It has been suggested that many of these radiographs are unnecessary and that if they could be avoided there would be considerable financial savings. We reviewed the chest radiographs taken following pacing and at subsequent clinic attendances of 600 consecutive patients undergoing permanent cardiac pacing, in order to determine the incidence of radiologically apparent complications. We also reviewed the clinical notes of these patients to validate the correctness of radiological assessment. In all, 20.7% of patients had, at some stage, at least one radiologically apparent complication of pacing on a chest radiograph, 6.8% of these having potentially serious implications. Of these complications, 10.9% were related to pacing wire malposition, 4.9% to pulmonary abnormalities consequent on pacing and 4.9% to the presence of the pacemaker system in the tissues of the chest wall and venous system. Of the routine radiographs taken in patients with permanent pacing systems there is a high incidence of radiologically apparent complications, both immediately after insertion and later. Our study indicates that routine chest radiography in pacemaker patients is worthwhile and detects a significant number of important abnormalities. Examples of the specific abnormalities and details of their frequency are presented.

A review of the use of the pre-operative chest radiograph within a teaching hospital

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The Royal College of Radiologists (RCR) have produced guidelines for the use of pre-operative chest radiographs (POCR). The aims of this prospective study were to assess the number of POCRs performed at Manchester Royal Infirmary, monitor adherence to the RCR guidelines and to determine the proportion of POCRs which showed significant abnormalities. Prior to the study, all pre-registration House Officers had been circulated with details of the RCR criteria. Four 2-week periods were studied in which 300 POCRs were requested. Clinical data and radiological findings for each of these patients were abstracted; 33% of those radiographed did not comply with the guidelines. The proportion of patients lying outside the guidelines increased with age. There was little difference in the proportion of significant abnormalities in the group conforming to the guidelines (19%) compared with those not conforming (15%). Our conclusions are that stricter adherence to the guidelines should be encouraged and, in particular, it should be emphasized that age alone is not considered an indication for POCR.

Iotrolan in selective bronchography via the fibreoptic bronchoscope

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The standard technique of selective bronchography via the fibreoptic bronchoscope using Dionosil (Glaxo) has disadvantages. The medium is a thick suspension and is extremely difficult to inject via the fine catheter that is required to prevent the contrast medium blocking the endoscopic suction channel. In addition, Dionosil obscures bronchoscopic vision and may induce chemical pneumonia and lung collapse as well as compromise lung function if a large volume is used. We describe the use, safety, and efficacy of a non-ionic dimer, Iotrolan 240 (Schering AG), in a group of 11 patients (six male, five female, age range 34 to 72 years, mean age of 54 years) requiring selective bronchography. Indications for the bronchograms were suspected bronchiectasis (eight cases), solitary pulmonary nodule (two cases) and recurrent lobar collapse (one case). Arterial oxygen saturation was monitored continuously by pulse oximetry for 4 h from the beginning of the bronchoscopy. The bronchogram was diagnostic in nine cases (five bronchiectasis and four normal bronchial trees). The technique was easy and quick to perform (average time of 19 min per examination). Iotrolan was found to be safe and the only significant side-effects were nausea and vomiting noted in three patients. Four patients became significantly hypoxic (oxygen saturation less than 90%) during the procedure. In three cases this occurred before the administration of Iotrolan; the remaining patient had extensive bilateral bronchiectasis. In contrast to Dionosil, Iotrolan, being a solution, can be injected directly into the endoscopic suction channel, it does not obscure bronchoscopic vision and thus does not interfere with further procedures following the bronchogram, such as transbronchial biopsies. The relatively low viscosity led to overfilling of the distal air spaces and alveoli in normal lung segments, whereas in bronchiectasis adequate or underfilling was noted. Complete clearance of the contrast medium from the lungs usually occurred within 24 h of the examination.

Role of transthoracic needle biopsy of lung masses following unsuccessful transbronchial biopsy

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Fibreoptic bronchoscopy and transbronchial biopsy (TBB) are the mainstay of pathological diagnosis in focal lung disease. These procedures do not always yield pathological tissue. In patients with lung masses, transthoracic needle biopsy (TNB) is an established alternative diagnostic method. To evalute the role of TNB when TBB has been unsuccessful, we analysed the results of percutaneous biopsy in 129 patients with lung masses where TBB had not yielded a diagnosis. The lesion was central in 40 patients, apical in eight and peripheral in 81. Size ranged from less than 3 cm in 60 patients to greater than 6 cm in 29 patients: in 40 the lesion was between 3 and 6 cm in maximal diameter. In 12 patients where a lung mass and mediastinal nodes were present, the nodes were biopsied, obviating the need for mediastinoscopy. Transthoracic needle biopsy was performed on an average of 2.7 days after TBB: in 14 patients, TBB biopsies had been attempted more than once with inconclusive results (25% of patients had metastatic disease). Transthoracic needle biopsy was diagnostic in 114 out of 129 (89%) lesions and of the remaining 15, six were subsequently shown to be benign. The true negative rate for malignancy on TNB was 7%. From these results we suggest that a tissue diagnosis could have been more efficiently arrived at had TNB been considered as the initial biopsy procedure. Where TBB is not otherwise indicated, TNB is an excellent alternative first-line biopsy technique. It should be considered as the first biopsy procedure: (a) where the mass is thought unresectable due to extent, (b) where it is thought to be a metastasis, (c) in peripheral lesions less than 3 cm in diameter, (d) instead of a repeat previously failed bronchoscopy, (e) instead of mediastinoscopy when large anterior mediastinal nodes are present, and (f) apical (Pancoasts) lesions.

The value of chest radiography, computed tomography and radionuclide scanning in thoracoplasty/plombage patients: correlation with clinical and respiratory function

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A number of imaging techniques have been employed in the late follow-up of patients who have had previous thoracoplasty or pleural plombage. Although chest radiography demonstrates the skeletal, pleural and pulmonary abnormalities, computed tomography (CT) gives better anatomical detail when assessing bullous disease, pleural disease and bronchiectasis in these patients. Ventilation/perfusion radionuclide scanning gives functional but little anatomical information. The aim of the present study was to assess how well each of these three imaging techniques correlates with the clinical status and respiratory function, and to determine whether CT and radionuclide scanning are of greater clinical value than chest radiography. Twenty-eight patients with a thoracoplasty or pleural plombage were studied. All patients had full clinical, respiratory and radiological (chest radiography, CT and radionuclide scanning) work-up. Initial evaluation of the results shows a variable relationship between the imaging findings and clinical and respiratory function. This is most marked for ventilation/perfusion radionuclide scanning, but also occurred with chest radiography and CT. Specific features, including lung volume, lung parenchymal disease, pleural disease and bronchiectasis, demonstrated by chest radiography and CT have been individually assessed to try to improve the correlation with the clinical and respiratory function. Detailed statistical analysis of these results is presented. The variable relationship between the clinical and radiological findings indicates that chest radiography, which is inexpensive, will remain the routine imaging technique, with CT having a limited role in the follow-up of these patients.

Computed tomography or chest radiography in the assessment of response to radiotherapy in lung cancer

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The pilot study of continuous, hyperfractionated accelerated radiotherapy (CHART) included 52 patients with lung cancer. In order to obtain full information as to tumour response it was planned to perform CT every 2 months until 6 months and then continue at 2-monthly intervals in those with residual tumour, until complete regression or regrowth was observed. In those with complete remission, CT was routinely performed every 6 months. All patients also underwent monthly chest radiography until complete regression or regrowth, when the intervals were lengthened to 2 and later 3 months. An independent review of all the scans and radiographs has been performed and the assessments by CT and conventional chest radiography correlated with survival and local tumour control determined in long-term follow-up. In individual cases it was apparent that CT gave more detailed information and a decision regarding the response to treatment could be made more readily than with conventional radiography. All patients were followed-up carefully and post-mortem examinations requested, especially where there was any uncertainty about the condition of the primary tumour in the chest. The evidence favours CT as a means to obtain accurate data concerning tumour response and control after radiotherapy.

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